Proceedings of the Fourth Pacific Coast Herring Workshop October 7-8, 1981

Kurt Buchanan (Editor)

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Nanaimo, British Columbia V9R 5K6

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Canadian Manuscript Report of Fisheries and Aquatic Sciences

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Rapport manuscrit canadien des sciences halieutiques et aquatiques

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Canadian Manuscript Report of Fisheries
and Aquatic Sciences No. 1700

April 1983

PROCEEDINGS OF THE FOURTH PACIFIC COAST HERRING WORKSHOP

OCTOBER 7-8, 1981

by

Kurt Buchanan (Editor)

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Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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INTRODUCTION

In the five years since the 3rd Pacific Coast Herring Biologists Workshop in 1976, we have seen many developments in the herring fisheries, and considerable changes in management and research activities. Nearly 10 years of data are now available for some sac-roe fisheries, while new roe fisheries have developed in other areas only within the past few years. Diversification of the fishery to include bait and food has become an important component of the Canadian management strategy, to reduce dependency on the volatile roe market. Fishing for food herring in the open ocean off the United States has been strongly advocated by some components of industry, and just as strongly opposed by others. Stock condition for herring populations ranges from healthy and increasing to declining and possibly depressed. Stock assessment for the exploited populations has blossomed: tagging, hydroacoustics, spawning ground survey refinements, and mathematical modeling all play important roles as we try to match resource size with appropriate harvest levels.

For this fourth coast-wide workshop, we tried to emphasize specific, new developments, rather than regional overviews. Topics covered included current status of commercial fisheries, herring management plans and harvest strategies, pre-fishery stock assessment, spawning ecology, nearshore and estuarine studies, habitat protection, tagging, and other studies. The range of topics was wide, and certainly offered potential for a longer meeting. Manuscripts provided by speakers, and tape recordings of discussions during the sessions formed the basis for these proceedings. Many of the presentations and comments were made informally, and contain preliminary data or conclusions. Before citing this information, please confirm its suitability for publication with the author.

Bob Trumble
Washington Department of Fisheries
Workshop Chairman

INTRODUCTION

Au cours des cinq années qui ont suivi le 3e Colloque des biologistes sur le hareng de la côte du Pacifique, en 1976, nous avons constaté une évolution considérable de la pêche du hareng et des activités de gestion et de recherche. En ce qui concerne certaines pêches du hareng plein, nous disposons maintenant de données recueillies sur une période de près de dix ans et, ces dernières années, de nouvelles pêches du hareng plein ont été instaurées dans d'autres secteurs. La diversification des activités halieutiques, de manière qu'elles comprennent la production d'appâts et de hareng destiné à l'alimentation et qu'elles soient donc moins à la merci des fluctuations du marché du hareng plein, est devenue un élément important de la stratégie de gestion canadienne. Certaines composantes de l'industrie ont vivement préconisé la pêche en haute mer du hareng destiné à l'alimentation, au large des États-Unis, tandis que d'autres s'y sont opposés tout aussi fermement. L'état des populations de hareng varie: certains stocks sont florissants et s'accroissent, alors que d'autres diminuent et sont peut-être en train de péricliter. L'évaluation des stocks des populations exploitées s'est beaucoup perfectionnée: l'étiquetage, l'hydroacoustique, le perfectionnement des techniques de levés dans les frayères et la modélisation mathématique jouent tous un rôle important dans nos efforts en vue de bien coordonner la quantité de ressources et les niveaux d'exploitation.

Nous avons tenté d'axer ce quatrième colloque, organisé pour l'ensemble de la côte, sur des progrès particuliers plutôt que d'effectuer des survols régionaux. Parmi les questions examinées, signalons l'état actuel des pêches commerciales, les plans de gestion du hareng, les stratégies de pêche, l'évaluation exploratoire des stocks, le milieu de reproduction, des études littorales et estuariennes, la protection de l'habitat, l'étiquetage et d'autres études. La vaste gamme des sujets à l'étude aurait certainement pu justifier la tenue d'un colloque plus long. Le présent compte rendu s'inspire des manuscrits fournis par les conférenciers et de l'enregistrement des discussions. Bon nombre des intervenants ont fait des présentations et commentaires officieux, reposant sur des conclusions ou données préliminaires. Avant de citer ces renseignements, veuillez demander à l'auteur s'ils peuvent être publiés.

Bob Trumble
Ministère des Pêches de l'État de Washington
Président du Colloque

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FOURTH PACIFIC COAST HERRING BIOLOGISTS WORKSHOP
Mayflower Park Hotel, Seattle
October 7-8, 1981

FINAL AGENDA

October 7

WELCOME Bob Trumble

SESSION I: Current Status and Management Problems of Commercial Fisheries - Steve Fried - Moderator

a) Alaska - Steve Fried and Craig Whitmore, ADFG
b) British Columbia - Lloyd Webb, F&O
c) Washington - Kurt Buchanan, WDF

BREAK

d) Discussion

LUNCH

SESSION II: Regional and International Herring Management Issues - Bob Humphreys, F&O, Moderator

Panel Members:
Al Millikan - WDF
Bob Trumble - WDF
Bob Humphreys - F&O

a) Potential U.S. offshore herring fishery - Al Millikan, WDF
b) Stock assessment using catch and spawn data - Doug Hay, F&O
c) H-Model: a harvest strategy model - Bob Trumble, WDF
d) Sampling design for herring roe stock assessment and management - Jake Schweigert, F&O

BREAK

SESSION III: Pre-Fishery Stock Assessment Techniques - Norm Lemberg, WDF, Moderator

a) The reliability of hydroacoustic estimates - Fred Taylor, F&O
b) Herring off the west coast of Vancouver Island, 1980-81 - Fred Taylor, F&O
c) Aerial surveys in western Alaska - Steve Fried, ADFG
d) Discussion

October 8

WELCOME BACK

SESSION IV: Spawning Ecology; Innovations in Spawn Surveys - Max Stocker, F&O, Moderator

October 8 (cont'd)

- a) British Columbia - Carl Haegele, F&O
- b) Roe-on-kelp research at Bristol Bay, Alaska - Mike Stekoll, UA, Juneau
- c) Juvenile herring habitat at two spawning areas in the Strait of Georgia - Colin Levings, F&O
- d) Discussion

BREAK

SESSION V: Habitat Protection - Bob Trumble, Moderator

LUNCH

SESSION VI: Other Studies - Doug Hay, F&O, Moderator

- a) Larval survival and recruitment - Doug Hay, F&O
- b) Trophic ecology of herring in Puget Sound - Kurt Fresh, WDF
- c) Parasites as biological tags - Mike Moser, UC, Santa Cruz
- d) Scale pattern analysis techniques - Kathy Rowell, ADFG
- e) Discussion

BREAK

SESSION VII: Tagging - Kurt Buchanan, WDF, Moderator

- a) B.C. tagging program - Carl Haegele, F&O
- b) Tag retention and survival in captivity - Doug Hay, F&O
- c) Fluorescent pigment - Gary Gonyea, WDF
- d) Internal coded wire tag - Keith Jefferts, NMT
- e) Discussion

CLOSING COMMENTS - Bob Trumble

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- Dean Mike
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- John Boettner
- Tom Dark
- Tom Edwards
- Jim Gibson
- Kris Kwarfel
- Mike Mackay
- Pat McAllister
- Mary Lou Mills
- Dan Penttila
- Dick Thorne

SESSION I:

CURRENT STATUS AND MANAGEMENT PROBLEMS OF COMMERICAL FISHERIES

MANAGEMENT OF PACIFIC HERRING, Clupea harengus pallasi IN WESTERN ALASKA

Stephen M. Fried and Craig Whitmore
Alaska Department of Fish and Game
Anchorage, Alaska

INTRODUCTION

During 1959-1976, foreign nations (primarily Japan and U.S.S.R.) harvested large amounts of eastern Bering Sea Pacific herring, Clupea harengus pallasi, in offshore trawl and gillnet fisheries (harvest range: 8,000-146,000 m.t.; harvest mean: 45,000 m.t.). Upon passage of the Fishery Conservation and Management Act in 1976, the available yield of herring was transferred to domestic fisheries regulated by the Alaska Board of Fisheries (inshore waters from coast to three miles) and the North Pacific Fisheries Management Council (offshore waters from 3 to 200 miles). Commercial herring harvests in western Alaska rose dramatically from an average of 63.9 m.t. during 1967-1976, to an average of 12,170.5 m.t. during 1977-1981 (Fig. 1, Table 1). Value of the harvest to fishermen rose from $0.4 million in 1977 to a high of $8.2 million in 1979 (mean: $4.3 million, 1977-1981). Most of the harvest was taken for sac roe, little was used as food or bait. A roe-on-kelp harvest has also developed in which participation is largely by local residents (harvest range: 4.6-207.1 m.t.; mean: 81.4 m.t., 1968-1981).

Prior to 1978, the inshore fishery developed without regulatory restrictions. During the past four years, however, the Alaska Board of Fisheries adopted several regulatory measures concerning seasons and fishing period, gear specifications, boundaries and catch reporting to ensure that harvestable surpluses were not exceeded as fishing effort increased. Use of gillnet gear is permitted in all fishing districts, however, purse seine gear is permitted only in Togiak and Port Clarence. Due to lack of knowledge about stocks, and in view of stock collapses which have historically occurred in other herring fisheries, harvest rates have been set at 10-20% of available biomass. The State has also adopted a policy of limiting harvests to inshore spawning areas so that exploitation rates on separate spawning stocks can be regulated. A conservative policy has also been taken for managing roe-on-kelp harvests, since recovery rates of harvested kelp beds are not known. Harvest rates have been set at 10% of available kelp biomass in designated areas.

Presently, no plan has been approved for offshore herring fisheries regulated by the North Pacific Fishery Management Council. However, a plan has been submitted which provides methods for estimating optimum yield and distributing it among user groups in the following order of preference: subsistence; inshore domestic commercial; offshore domestic commercial; offshore foreign commercial; offshore domestic and foreign commercial groundfish trawl fisheries. Presently, the National Marine Fisheries Service manages offshore herring resources under a preliminary plan. Except for allowable incidental catches of herring in groundfish trawl fisheries, no directed offshore fisheries for herring are permitted.

METHODS

Stocks of herring are assessed annually by aerial surveys conducted over the spawning grounds. No reliable method presently exists for making pre-season forecasts. Test fishing with variable mesh gillnets is conducted throughout the season to collect information on herring stock age structure, sex composition, size, and sexual maturity. Catches of other schooling fishes are used to adjust aerial survey results for occurrence of these fishes. Extent and occurrence of herring spawn is assessed during the season through aerial observations and ground surveys. Standing crop of kelp is assessed through ground surveys. Commercial harvests are recorded and tallied from hailed estimates during the fishery and from delivery receipts after the season. Catch sampling is conducted throughout the season to collect information on age, size, and sex of harvested herring.

DISCUSSION

The spawning grounds of eastern Bering Sea herring stocks cover a vast expanse of coastline (Port Moller to Bering Strait, approximately 4,000 km) characterized by rocky headlands exposed to extreme, unpredictable weather patterns and sea conditions. This area is remote, reachable only by boat or aircraft. These factors, coupled with extensive fishing effort during the spawning season (300-400 vessels are present just in Togiak District), seriously affect abilities to assess stocks through aerial surveys and make sampling programs difficult and hazardous. However, as fishing effort and harvest demands increase, all aspects of the fishery must be intensively monitored to ensure protection of herring stocks and spawning substrate while allowing optimum resource utilization. To maximize economic return to the industry, herring must be harvested just prior to spawning, when roe content is highest. Since herring arrive and spawn throughout a two-month period, real time management and assessment are difficult. Increased aerial coverage is needed to keep abreast of rapidly changing stock conditions. More information needs to be gathered so that the relationship between school density (tonnage per unit surface area) and water depth can be determined. Information on herring entry and exit patterns, along with estimates of residence time on the spawning grounds, would also improve the accuracy of aerial assessments. Test fishing coverage has often been minimal and the suitability of variable mesh gillnets as a sampling tool needs further study. Assessments of major kelp beds and spawn deposition are difficult to obtain due to the large geographic area involved, the limited time available for sampling, and the intensive manpower and logistic support required.

Presently, no reliable methods have been developed to forecast herring abundance prior to the fishing season or to set optimum spawning goals. Predictions are made concerning future spawning returns based only upon abundance of recruited year-classes (estimated through aerial surveys, test fishing, and catch sampling). No field programs have been developed to estimate the abundance of pre-recruit herring, although the National Marine Fisheries Service has attempted to use U.S.S.R. trawl survey data to accomplish this task. Optimum spawning goals cannot be set until several years of data concerning spawning biomass or, more importantly, spawn deposition become available.

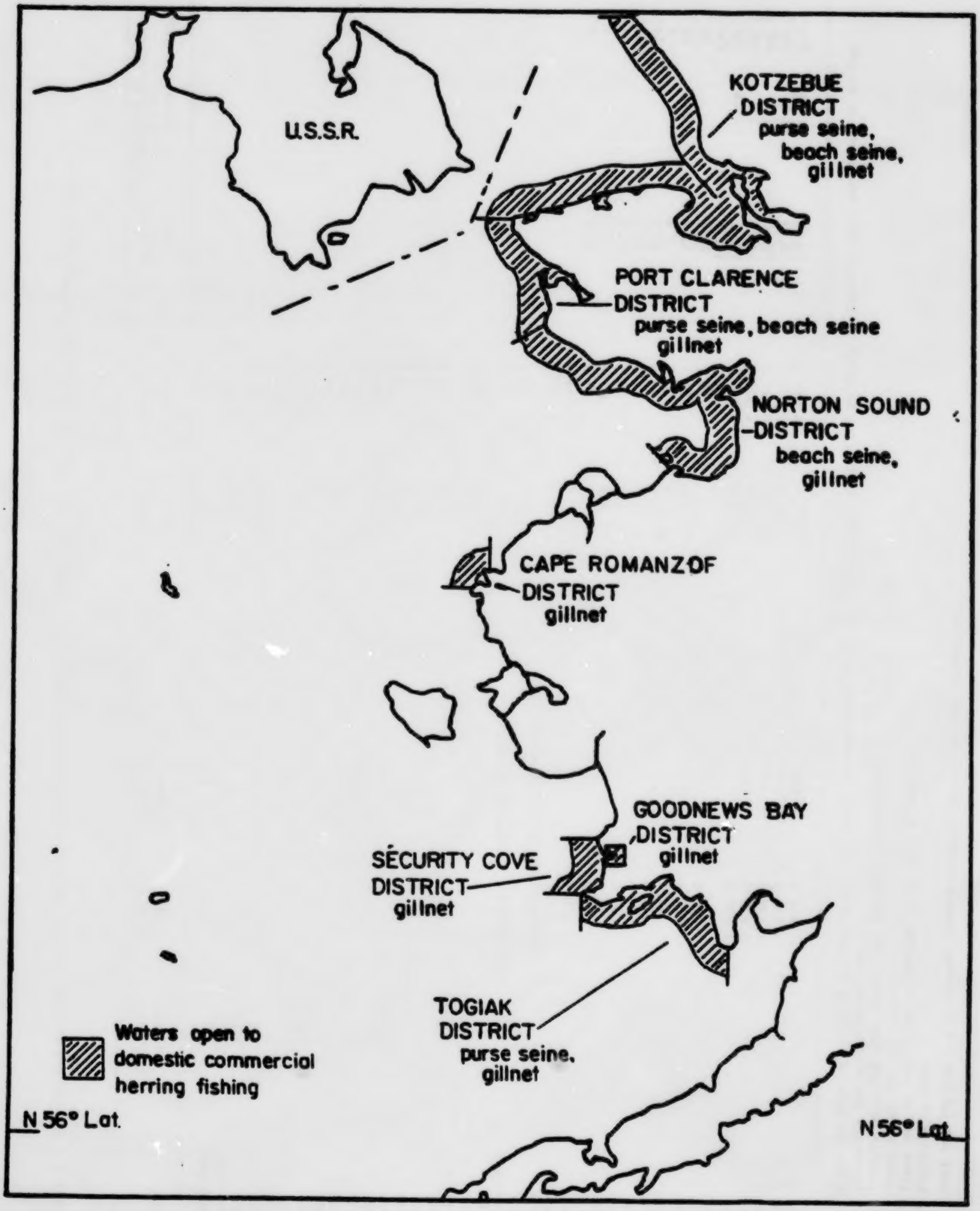

Fig. 1. Commercial herring fishing districts and applicable gear, eastern Bering Sea Alaska, 1981.

Table 1. Herring and herring spawn on kelp harvests in metric tons by U.S. commercial fishermen in the eastern Bering Sea, Alaska 1909 - 1981.

Year	Herring 1/						Herring spawn on kelp		
	Unalaska Island	Bristol Bay	Security Cove/ Goodnews Bay	Cape Romanzof	Norton Sound	Total	Bristol Bay	Norton Sound	Total
1909-1916					2/	2/			
1916-1928					1,705.6	1,705.6 3/			
1929	1,141.9				151.3	1,293.2			
1930	1,738.2				399.7	2,137.9			
1931	957.9				78.2	1,036.1			
1932	2,276.9				480.0	2,756.9			
1933	1,438.2				27.8	1,466.0			
1934	1,390.9				3.5	1,394.4			
1935	2,188.0				14.1	2,202.1			
1936	1,251.1					1,251.1			
1937	525.4				5.0	530.4			
1938	465.5				9.0	474.5			
1939					5.0	5.0			
1940					12.7	12.7			
1941					3.4	3.4			
1942-1944									
1945	68.0					68.0			
1946									
1947-1963		NO COMMERCIAL OPERATIONS REPORTED							
1964					18.1	18.1			
1965		NO COMMERCAIL OPERATIONS REPORTED							
1966					10.8	10.8			
1967		122.0				122.0			
1968		82.4				82.4	24.8		24.8
1969		42.8			2.0	44.8	4.6		4.6
1970		25.0			7.3	32.3	17.6		17.6
1971					17.7	17.7	23.5		23.5
1972		73.7			15.3	89.0	29.1		29.1
1973		46.3			32.3	78.6	5.3		5.3
1974		111.7			2.4	114.1	57.0		57.0
1975		50.4				50.4	50.4		50.4
1976					7.7	7.7	134.1		134.1
1977		2,534.9			9.5	2,545.4	125.1	trace	125.1
1978		7,030.4	259.0		13.6	7,303.0	149.6	3.4	153.0
1979		10,115.3	466.0		1,173.0	11,754.3	188.0	11.8	199.8
1980 5/		17,774.0 4/	1,039.0	554.0	2,215.4	21,600.3	86.0	22.2	108.2
1981 5/		11,374.3	1,660.2	653.2	3,964.5	17,652.2	171.9	37.2 6/	209.1

1/ Prior to 1964 majority of herring catch was taken in summer and fall for food market; since 1964 majority of herring catch was taken in spring primarily for marketing of roe.

2/ Fishery occurred some years, but harvests unavailable.

3/ Total catch for all years.

4/ There was an additional estimated 5,200 m.t. of wastage.

5/ Preliminary data.

6/ Does not include 5 m.t. dumped (unmarketable or no market when harvested).

CURRENT STATUS AND MANAGEMENT PROBLEMS, B.C.

Lloyd Webb
Fisheries and Oceans, Canada
Vancouver, B.C.

CURRENT STATUS OF STOCKS

For a number of years (since 1974) the PBS in Nanaimo has published, for example, "Preliminary forecasts of available roe catch from B.C. herring management units in 1978 and assessments of abundance in 1979". These manuscript reports calculate a catch level at which stocks may be safely exploited and give the district fishery officers a target for optimal size of spawning escapement. These catch level predictions are adjusted or tabled by poor, average, or good levels of recruitment of "first time" spawners and number of return spawners (based on biological samples taken during fisheries). The mechanics of the population models used in this exercise are currently being questioned by other (other than the authors) scientists. This, of course, is not surprising as it appears to be the role of the scientific community to question that which they may deem questionable. In any event regardless of which scientific group it is that uses this basic data (spawn or millions of eggs, catch data, and age compositons of stocks) the tonnages appear far in excess of any old time Pacific Coast seine fisherman's wildest dreams, or any semblance of what fishery officers are finding in their unsophisticated method of hydroacoustically estimating the stocks on each of the fishing grounds prior to fishery opening. At any rate the data we have indicates that stocks do not seem to be at a strength coastwide comparable to the reduction fishery years. Despite our local controversy as to who knows best the last word would have to be given to the researcher. Generally, it could be said that stocks in the northern areas have not completely recovered from the reduction fishery crash of the late 1960s. The southern stocks however, seem to have almost recovered to their former strength. Total B.C. stocks are estimated to be around 300,000 metric tons.

CATCH LEVELS

Food and bait fishery

Food and bait fisheries in recent years have been utilizing around 10,000 tons annually; generally around 7,000 tons from the Strait of Georgia and the balance from Northern and Central B.C.

Problems have occurred with quality of the herring in fishermen's landings. A gold rush attitude is created by large numbers of vessels competing for highly concentrated shoals. All vessels land their catch at the same time, consequently the processing/freezing plants cannot cope with the volume. The worst year was 1979 when almost 80% of food herring landings were deemed for use as bait when 20,000 metric tons were landed in a very short time. Since 1979 more emphasis has been put on gauging fishery openings with plant capacities, and restructuring entry requirements, i.e., 25 ton load limits, 18 hour delivery time and 24 hour processing limit, and requiring all vessels to have RSW and CSW refrigeration systems.

Current year food and bait catches are set at:

Queen Charlotte Islands - 500 tons;
Northern Area - 2,000 tons;
Central Area - 500 tons;
Strait of Georgia - 7,000 tons.

An anticipated 150 vessels fishing (80% seine, 20% trawl) have a demonstrated fishery power that would make any cold storage operator shudder. Fishery officers have quite a task on their hands to control the catch to around 1,500-2,000 tons per day. Local plant capacity is deemed to be 1,900 tons per 48 hour period in southern B.C.

The roe herring fishery

From a high of 80,000 tons in one season in the mid-1970s the catch dipped to around 30,000 tons in 1981. Anticipated catch for 1982 season will be at about 35,000 tons.

Prior to the 1981 season many problems related to the execution of fisheries occurred such as:

1. Too many seine vessels to open on small available tonnages.
2. Roe yields not sufficient to open even though sufficient stock in area.
3. High mobility of fleet compounded overcrowding of grounds.
4. Discharge of pollution on spawning grounds.
5. Noise levels on grounds frightened stocks away.
6. Huge seine sets split and lost on grounds.
7. Gillnet shaker dropout.

The fishing industry looked to the Department for increasingly more accurate data with regards to strength of runs, location specific, in order to be at the right place at the right time.

Fortunes were made during the boom year of 1979 when 42,800 m.t. earned some 1,300 gillnet and 250 seine 182 million dollars. The landed value has, of course, dropped significantly whereby in 1981, 23,000 m.t. earned non-union fishermen $22.6 million. In other words, landed values dropped from highs of $4,000/ton to around $1,000/ton.

In 1981 the Department of Fisheries implemented an area licensing scheme that separated the fishing fleet as follows:

Area A - North of Cape Caution	Seine - 98	Gillnet - 387
Area B - Strait of Georgia	Seine - 37	Gillnet - 501
Area C - West Coast of Vancouver Island	Seine - 102	Gillnet - 400
	237	1,288

Fishermen were given their choice to fish only one of the above areas. They based their choices on projected catches by area and spawn assessments made the season before. Fishermen were given one chance to change the choice of area to be fished and luckily no disproportionate number of vessels in any area occurred. The system was not without its problems though. A few of the main problems were:

1. More pressure was put on fishery officers to open their respective areas. Since the fleet could not go to another place they put more pressure on the fishery officer to open.
2. More vessels than normal showed in locations where small fisheries could have taken place with fewer vessels (mainly a seine problem).
3. Although there were sometimes fewer seine vessels at normally large fishery locations, often times there were as many as in prior years.

Questionnaires sent to fishermen after the 1981 area licencing program indicated to us that they liked it enough to request that we implement the program again in 1982. Steps are now being taken to smooth out some of the rough spots on the three area licence system by:

1. Beginning the program mid-November (area choice selection by fishermen),
2. Write or re-write regulations to ease enforcement and resultant court work loads (i.e., use of decals to indicate area choice; gillnets may use only one licence per punt, etc.),
3. Improve our charter vessel program to meet the new needs of fishery managers,
4. And most importantly, to draw upon the wealth of skill and knowledge of our scientific community into the base level of fishery management - executing the fishery.

MAJOR PROBLEMS

Two major problems in herring management

1. Allocation - who gets the resource - locked into old players (grandfather rights) makes it difficult to make wholesale changes, i.e. a) vessel quotas (tenure), b) timber lease system.

   Regulation changes presently require more than 100 days to promulgate making long term planning a must.

2. Stock Status - geographic management of stocks would be much easier if we knew precisely the following:
   a) migratory route of all stocks
   b) absolute stock size
   c) absolute optimum escapement levels - hence catchable surplus.

Other problems

Too many fishermen presently seeking too few fish. How do we respond to such a problem. A few suggestions follow but no clear "best way". Possibly:

1. licence or vessel buyback,
2. economic starve-out (that will be long term and hard on the survivors),
3. permit system or equally divisable vessel (licence) quotas.

Lack of funding to pay for resource charters. Currently, we pay direct from the herring resource (tons of fish/charter days work). We are also compromising our research or in some areas spreading it over a very long period. I see this as particularly regressive.

High point in B.C. herring management

Directors are now actively seeking out those researchers, biologists, economists, and technicians with an interest in herring management. We are slowly building a base of people that have expertise in this field. While it is obvious by my prior statements of underfunding, we are resourceful in the calibre of people now working to maintain and enhance B.C.'s rich herring resource.

HERRING FISHERIES IN WASHINGTON

Kurt Buchanan

Washington Department of Fisheries
Seattle, Washington

Management of commercial herring fisheries in Washington is guided, in part, by a series of U.S. Federal Court decisions, and by limited entry legislation. In 1974, the decision of U.S. Federal District Court Judge Boldt upheld the rights of certain treaty Indian tribes to fish at "usual and accustomed" areas, and to a percentage of the harvest. This "Boldt decision" originally applied only to salmon and steelhead; now it applies to all herring fisheries. Eleven treaty Indian tribes now have herring fishing rights which entitle them to 50% of the harvestable quantity of herring. There is little Indian participation currently in either the sport bait or general purpose fisheries, consequently only sac-roe fishing is managed on a formal 50-50 allocation basis. In 1973 and 1974, legislation was enacted limiting the number of non-treaty fishermen participating in herring fisheries to those who had validated herring landings during a specific qualifying period. There are provisions for certain hardship case validations, as well as a mechanism to replace purse seine validations with gillnet validations, and vice versa. All validations are transferable. Limited entry applies only to the non-treaty fleet; there are no growth limits on the treaty Indian fleet. At present, the non-treaty herring fleet size is as follows: 31 purse seine, 4 purse seine-bait only, 6 gillnet, 43 lampara, 43 dip-bag, and 1 brush weir. The treaty Indian fleet has approximately 20 seiners and at least 200 gillnetters. The treaty Indian fleet is active primarily in the sac-roe fishery, to a lesser degree in the general purpose fishery, and not at all for sport bait. The non-treaty fleet is active in all three.

Fishing for sport bait occurs throughout Puget Sound on a year round basis, and targets primarily on 6 inch herring (plugs). Adults and young-of-the-year are harvested to a lesser extent. Salmon sport fishermen provide the main market for this fishery; some bait also goes to commercial salmon trollers, crab fishermen, and zoos and aquaria. The catch trend from the 1950's to the 1970's (Fig. 1) was of slowly increasing landings as demand for sport and commercial bait increased. Restrictions in the commercial and sport non-treaty salmon fishery required by the Boldt decision has recently lowered the demand for sport bait. The main gear used in the sport bait harvest is the 200 ft lampara net, and approximately 10 out of 42 validated lampara fishermen are actively involved. The dip-bag net is of secondary importance, followed by beach seine and 600 ft purse seine. Market limitations and restrictions on gear size reduce the need for active management. The stocks supporting this fishery are not well defined in spite of numerous stock assessment surveys. It is not yet possible to predict either the abundance of juvenile herring available to the fishery during a given season, or the contribution of these juveniles to the subsequent adult spawning population. There are, however, some promising indications that young-of-the-year herring abundance may yet provide a prediction of its subsequent year-class strength.

The general purpose fishery occurs in northern Washington waters during December and January with major landings now from the Bellingham Bay area. Until the early 1970's, herring were used for reduction to oil and meal. Reduction became uneconomical, and now the product is boxed and used primarily as king crab bait. Fishermen use 1,650 ft long by at least 120 ft deep purse seines; mid-water trawl and gillnet are not legal gear. Until recently, only 6 to 8 of the eligible, non-treaty fishermen participated. In the past 2 seasons, there have been a maximum of 18 boats involved. A small number of treaty Indian vessels are also involved, but as yet this fishery is not managed on a treaty/non-treaty allocation basis. During the past few seasons, there has been a decline in both the mean length and mean age of fish landed, and an increase in total tonnage. In earlier years, mean length was 175 mm SL, and mean age between 3 and 4 yr old. During the 1979-80 and 1980-81 seasons, the mean length was 150 mm SL, and the mean age 2 yr old. The harvest was restricted for the first time during the 1980-81 season, both in tonnage landed and times and areas fished. The 1981-82 season will be managed to restrict the harvest of small herring. The quota will be set at 20% of the acoustic biomass of "adult" herring in the fishing area, and no more than 25% (by number) of the harvest can be shorter than 152 mm SL (7 inch TL).

A fishery for sac-roe, begun in 1973, is conducted from late April through early May in the eastern Strait of Georgia and Hale Passage. Whole herring are boxed and frozen for export; roe is not processed in Washington. This fishery is the only one in which the catch is allocated 50-50 between treaty Indian tribes and non-treaty fishermen; the State and these tribes jointly manage the harvest. During the season, the non-treaty fleet of 31 seiners and 6 gillnetters all participate as well as the treaty Indian fleet of approximately 20 seiners and over 200 gillnetters. The combined fleet size has many times the fishing capacity than is necessary and is able to catch a substantial part of a year's quota in a single day. In recent years, the average total catch has been approximately 2,000 tons. The catch is governed by a quota, originally at 20% of the spawning population and more recently 16%. Fishing may occur only if the spawning population exceeds 9,000 tons. Spawning population size is determined initially by a series of hydroacoustic-midwater trawl surveys, and subsequently by the catch and spawning escapement estimates. The population size, and consequently the harvest has been decreasing over the past few years. The population age structure also has been of concern with the mean length and mean age decreasing. In the early years of the fishery, the catch was primarily 4 yr or older. In 1980, for the first time, 2 yr old herring (1978 year-class) formed the dominant year-class in both the population and catch. Without this large contribution of 2 yr olds, there would have been too few fish for a fishery. In 1981, due to lower abundance and strict conservation measures to protect the 1978 year-class, the fishery did not open.

For many years there has been a cooperative data exchange between Washington and B.C. herring biologists. Recently this has been expanded to a tagging program conducted in both areas. Returns of tagged herring from both the southeast Vancouver Island area and the eastern Gulf of Georgia imply a connection between stocks harvested in both countries. A comparison of biological characteristics is proposed for herring harvested in the B.C. fall-winter food fishery and those in the U.S. spring sac-roe fishery. Hopefully, such cooperative analysis and continued research will aid in stemming the apparent decline of Washington's largest run of herring.

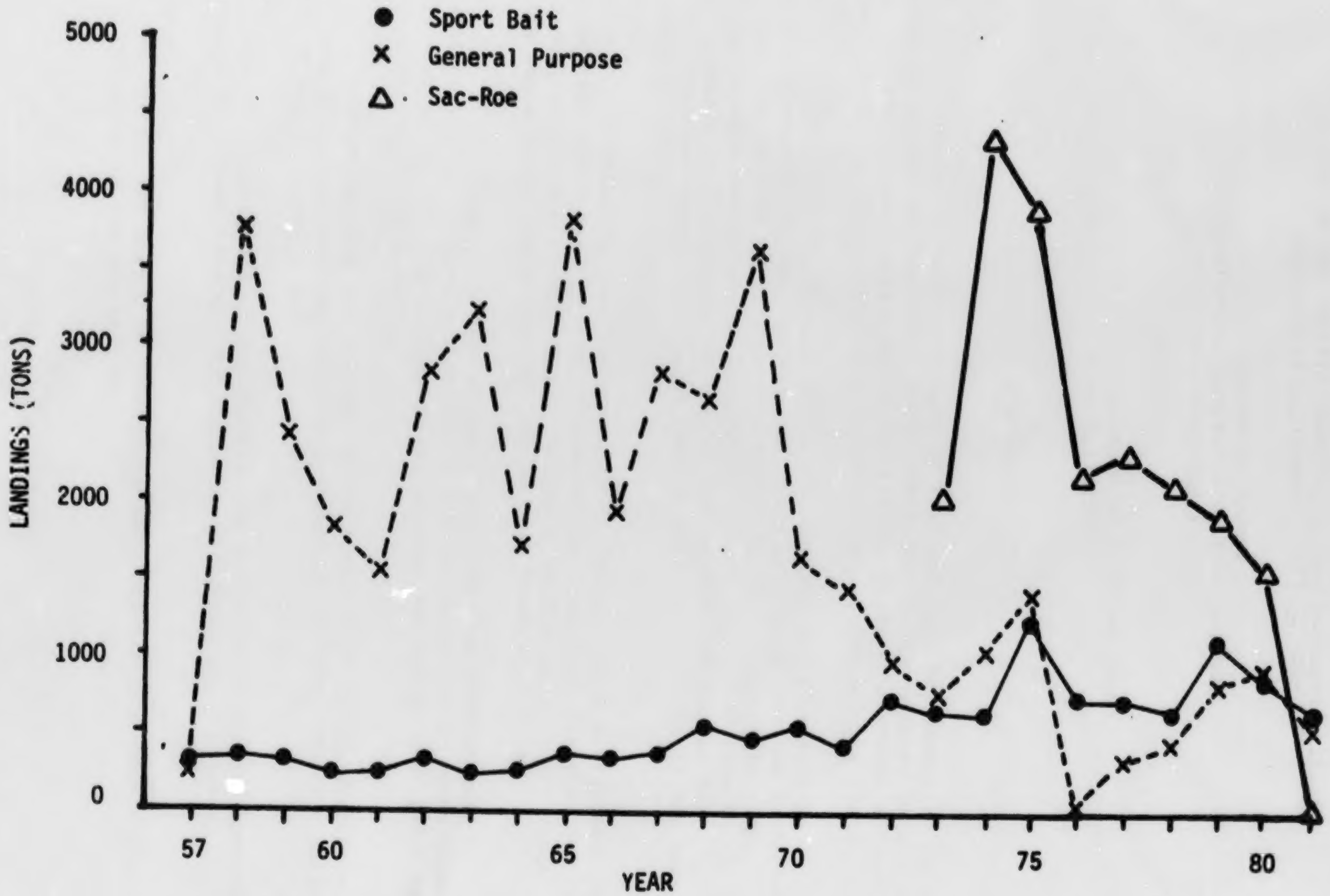

Figure 1. Commercial herring landings in Washington state, 1957-1981.

STATUS OF THE PACIFIC HERRING, *Clupea harengus pallasi*, RESOURCE IN CALIFORNIA, 1972 to 1980

Jerome D. Spratt
California Department of Fish and Game
Monterey, California

California Department of Fish and Game
Fish Bulletin 171

ABSTRACT

The California Department of Fish and Game has conducted periodic studies on Pacific herring since 1953. This report concentrates on the period from 1972 through 1980 during which the herring fishery underwent a dramatic resurgence due to the opening of a lucrative market for herring roe in Japan.

The spawning biomass of Pacific herring was estimated by determining numbers of eggs spawned and using previously derived estimates of eggs per gram of fish to convert this figure to short tons of herring. Spawning biomass estimates for Tomales Bay ranged from 4,728 tons in the 1974-75 season to 22,163 tons in the 1977-78 season. Estimates for San Francisco Bay ranged from 6,179 tons in 1973-74 season to 52,869 tons in the 1979-80 season.

Sampling the roe fishery catch in Tomales and San Francisco bays revealed that age 2 and 3 herring dominated the round haul fishery, and ages 5 and 6 dominated the gillnet fishery. Gillnets consistently caught larger herring and a higher percentage of females than round haul nets.

Comparison of length at age of herring from Tomales and San Francisco bays revealed a statistical difference in growth rates between populations of the two bays. Tomales Bay herring are larger at a given age than San Francisco Bay herring.

Spawning time was related to the tidal cycle in San Francisco Bay. From 1973 through 1976, 88% of all spawnings occurred when the daily high tide was at night.

The resurgence of the fishery and evolution of current management strategies of quotas, seasons, and resource monitoring are discussed.

Note: Mr. Spratt was unable to attend the workshop, but sent this summary for inclusion in the Proceedings.

SESSION II:

REGIONAL AND INTERNATIONAL HERRING MANAGEMENT ISSUES

POTENTIAL U.S. OFFSHORE HERRING FISHERY

Al Millikan

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Seattle, Washington

I. Fishery from 3-200 miles offshore managed regionally, not state by state.
  A. Managed since 1976 by Pacific Fishery Management Council composed of Washington, Oregon, and California.
  B. A Herring Management Plan, to be implemented by the Council, is nearly complete.
    - In part this Plan deals with potential commercial fisheries.

II. Interest in a U.S. offshore fishery.
  A. Inshore fisheries are fully utilized in the three member states.
  B. Food herring is approaching the value of roe herring.
  C. A general feeling by the public that best use is as human food.
  D. Large quantity of food quality herring during summers off Washington Coast.
  E. As much as 80% may be of Canadian origin, so harvest would probably have little impact on inshore U.S. spawning stocks.
  F. Potentially could be harvested exclusively by U.S. fishermen.

III. Alternate future actions by Regional Council.
  A. Should herring management planning process continue.
  B. Should there be an offshore fishery.
  C. If so, how much should be harvested.

IV. The Regional Council and authors of Herring Management Plan don't actively advocate such a fishery but consider it an option.

DISCUSSION

Unknown number of U.S. origin herring available for B.C. harvest. Old and new tagging data suggest that offshore fish are mainly from southeast Vancouver Island-Gulf of Georgia, and some fish of Puget Sound origin. There may be another transboundary interception potential between Alaska and B.C., and between B.C. and Washington in inside waters. More information is needed on the composition of the summer offshore stock, but no additional cooperative U.S.-Canada investigations are currently planned. The degree of gonad maturity between various stocks may be useful in stock identification, however, in the ocean, stocks are probably randomly mixed as would be the harvest. There are usually two years of pre-recruit fish offshore in summers, with many juveniles present by September. An unknown number, potentially great, may be destroyed when passing through trawl meshes. Some herring stocks may be harvested twice already, both prior to and at spawning. Perhaps it's unwise to potentially impose a third fishery on these stocks before a thorough understanding of the effect of continued fishing at current levels. No conclusions were drawn by the end of the discussion period; many concerns remain.

STOCK ASSESSMENT OF PACIFIC HERRING USING CATCH AND SPAWN DATA

Doug Hay

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ABSTRACT

Cumulative lengths of annual spawn deposition, measured for the last 30 yr are inversely correlated to the magnitude of annual catches. For the British Columbia coast as a whole, the relationship is linear, statistically significant ($p<<0.01$) with a correlation coefficient of 0.77. The biological basis for such a relationship is simple: during years of large catches, the stock's spawning potential is reduced (eggs are removed in the catch) and this is reflected in reduced cumulative lengths of spawn; during years of small catches the spawning potential is not significantly reduced and cumulative spawn lengths are generally high. Therefore, this highly significant negative regression between catch and spawn lengths throughout the years provides a basis for directly relating the spawn lengths to the tonnage of fish required to deposit a linear km of spawn. Also, estimates of the variance of the slope of the line provide a basis for the application of confidence limits to the estimate of spawning stock abundance.

For the B.C. coast at large, the total mean stock size for the last 30 yrs is estimated at approximately 380,000 tons on the basis that each 1.61 km of spawn represents 1,000 tons of spawning stock. Analysis of the catch-spawn data from three smaller component regions, the Strait of Georgia, the west coast of Vancouver Island, and the combined north and central coast, yield slightly different estimates of tonnage per km of spawn, probably because of different average widths of spawn in each area. However, the difference among the areas is not substantial because the sums of the mean annual abundance from the individual areas (420,000 tons) is fairly close to that of the coast as a whole (i.e., 380,000 tons).

As a method of stock assessment the main advantage of this method is that it is simple and requires no data on assumptions on age structure, mortality, growth or fecundity rates, or catch-per-unit effort data. The few assumptions required for the application of the method can be formulated in terms of explicit hypotheses and tested. The main disadvantage is that the final estimates of stock abundance can only be approximate (i.e., in most cases ± 30%) and applicable only to relatively large geographic areas such as the Strait of Georgia or west coast of Vancouver Island.

H-MODEL: A HERRING HARVEST SIMULATION MODEL

Bob Trumble

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As part of the Pacific Fishery Management Council's development of a herring Fishery Management Plan, a simulation model of inshore and offshore harvest strategies was devised. The model is not a year to year predictor, but provides insight for effects of harvest on catch, population size, and spawning escapement. Details of the model are included in the PFMC Pacific Herring Fishery Management Plan.

The model is based on a traditional fisheries yield-per-recruit concept (Ricker 1975; Beverton and Holt 1957). Each year is divided into time periods in which factors of recruitment, growth, and mortality can be assumed constant. Standard fishery equations (growth and mortality are applied exponentially) allow biomass and harvest calculations for each time interval.

Such simulation models must be used with caution. Recruitment cannot be accurately predicted in advance so simulations can only give long term averages. Serial correlation of strong and poor recruitments is not considered. The model does not address the problem of discrete herring stocks mixing in fishing areas. Although the model cannot be used to accurately predict the course of events in a given year, it does give our best estimate of the long term consequences of different harvest management strategies.

Figure 1 shows the time periods (I-IV), the monthly instantaneous rates (M, F_o, F_s, G), fishing quotas (Q_o, Q_s), and recruitment (R) which are needed to go through the model's calculations. For example, in Period I, the year starts April 1 with an estimate of spawning escapement (B_s) following an inshore roe fishery. For a period following spawning, biomass will decrease due to natural mortality (M), although the decrease will be partially offset by growth (G). Hence, for biomass (B_o) three months after spawning, $B_o = B_s \exp[-3(M-G)]$.

If offshore fishing mortality (F_o) occurs for three months in the summer, the biomass following fishing (B_f) becomes $B_f = B_o \exp[-3(M+F_o-G)]$. Calculations in other periods follow this pattern.

A herring spawner-recruit relationship in the model assumes that recruitment varies independently of escapement above a threshold value of escapement; the average recruitment from escapements exceeding the threshold value is called Rmax. Below the threshold value, recruitment decreases linearly to zero as escapement decreases to zero. The predictive value of this relationship is poor, however, because of the extreme environmentally-caused fluctuations in recruitment, and because of the difficulty in determining the threshold value.

In order to simulate variability which occurs in a natural system, stochastic variation is included in three areas of the model. Variation is included as a log normal error, added to the variable X, by forming:

$$y = X\epsilon \text{ where } \log(\epsilon)\text{-}N(0,\sigma^2).$$

Stochastic variation is applied to recruitment ($\hat{R} = R'\epsilon$), and to biomass used for quotas ($\hat{B} = B\epsilon$).

Harvest strategies simulated by the model include combinations of a constant quota, a quota proportional to biomass, and a quota of all fish surplus to a spawning reserve. A provision exists for no harvest if biomass is less than a "shut-off" level. These are generalized in an equation

$$Q = \delta + \beta(\hat{B}-\alpha),\ \tau$$

where Q = annual catch
δ = a constant catch level
β = a constant harvest proportion
α = a reserve population
τ = a switch that sets $Q = 0$ if $\hat{B}<\tau$
$\hat{B}$ = estimated biomass at the start of fishing.

The parameters α, β, δ, τ are set by the manager; by setting combinations of the parameters to zero, harvest strategies can be simulated. For a constant quota (δ strategy)

$$\beta = \tau = 0,\ \delta>0$$
$$\therefore Q = \delta.$$

For a quota proportional to total biomass (β strategy)

$$\delta = \alpha = \tau = 0;\ 0<\beta\leq 1$$
$$\therefore Q = \beta\hat{B}.$$

For a quota proportional to biomass in excess of a reserve (α strategy)

$$\delta = \tau = 0;\ 0<\beta\leq 1$$
$$\alpha>0$$
$$\therefore Q = \beta(\hat{B}-\alpha)$$

when $\beta=1$, all fish in excess of the reserve will be harvested.

For results to be useful there must be confidence that the model responds in a way that is expected from theory. The simplest comparison to consider is the long term average population biomass expected when no fishing occurs. Theoretically, $\bar{B} = \bar{R}/Z$ (Ricker 1975) where $\bar{B}$ is average biomass, $\bar{R}$ is average recruitment, and Z is total mortality. For $\bar{R}$ = 100,000 tons and $Z = M-G = 0.3$, $\bar{B}$ = 100,000/0.3 = 333,333 tons. The model calculated an average spawning escapement (B_s) of 337,645 tons for a 100-yr simulation. Similar agreements occur for other combinations of $\bar{R}$ and Z. The model simulates average long-term conditions in a manner expected from theory.

The model offers a wide variety of management strategies, but to introduce the types of results possible, initial discussion will concentrate on inshore harvest only. Unless otherwise specified, results are based on the parameters $M = 0.4$, $G = 0.1$, $R_{max} = 100,000$ tons, with simulations of 100 years. The coefficients of variation of the three stochastically-influenced variables (R, $\hat{B}_O$, $\hat{B}_I$) are all 0.2.

The model was run for a constant harvest proportion (β strategy, $Q = \beta_s \hat{B}_I$) ranging from β_s=0.2 to β_s=0.6. At β_s= 0.2, the population and harvest were stable for the entire 100 years (Fig. 2). Spawning escapement averaged 172,830 tons with a standard deviation of 20,273. Harvest averaged 44,959 tons with a standard deviation of 9,636 tons. An increase of β_s to 0.4 caused a long-term decrease to near zero levels (Fig. 3). However, the decline did not occur for over 25 yr, indicating that heavy fishing pressure may be maintained if recruitment cycles are favorable, but when an unfavorable recruitment cycle occurs, heavy fishing will drive the population to critically low levels. At β=0.6, the population trend is inexorably down, to near extinction in just over 10 years.

As a protective mechanism, one may use the τ parameter to prevent harvest at low biomass levels. At β_s=0.4 but τ_s=100,000 tons (i.e., $R=\tau=100,000$ tons), the population is protected against continuous decline (Fig. 4). For the first 25 yr with β_s=0.4, the biomass values track in parallel fashion for τ=0 and τ=100,000. However, once the critical recruitment problem occurs, the population rebounds off the reserve (τ), but crashes without the reserve. During the 100-yr simulation (Fig. 4), predicted harvest averages 54,264 tons with standard deviation of 21,624 tons. This harvest is higher than using β=0.2 (Fig. 2), but is also plagued by many years of zero harvest.

A contrasting strategy harvesting all fish above a spawning reserve (α strategy, $Q = \hat{B}_s - \alpha_s$) also shows long-term stability (Fig. 5) but with larger year-to-year variation than observed for the β strategy (Fig. 2). For α_s=150,000 tons, catches average 49,043 tons, but with a standard deviation of 41,316 tons. Many years have no harvest or very low harvest, but other years will have extremely large catches.

The conclusion from this set of runs is that a threshold, either a spawning reserve (α) or switch (τ) will protect against too high harvest. But neither of these strategies will be able to prevent large fluctuations in abundance or harvest. The least variation came from a constant proportion of harvest (β strategy). The switch τ is a good companion to the β strategy in case higher than desired harvest inadvertently occurs.

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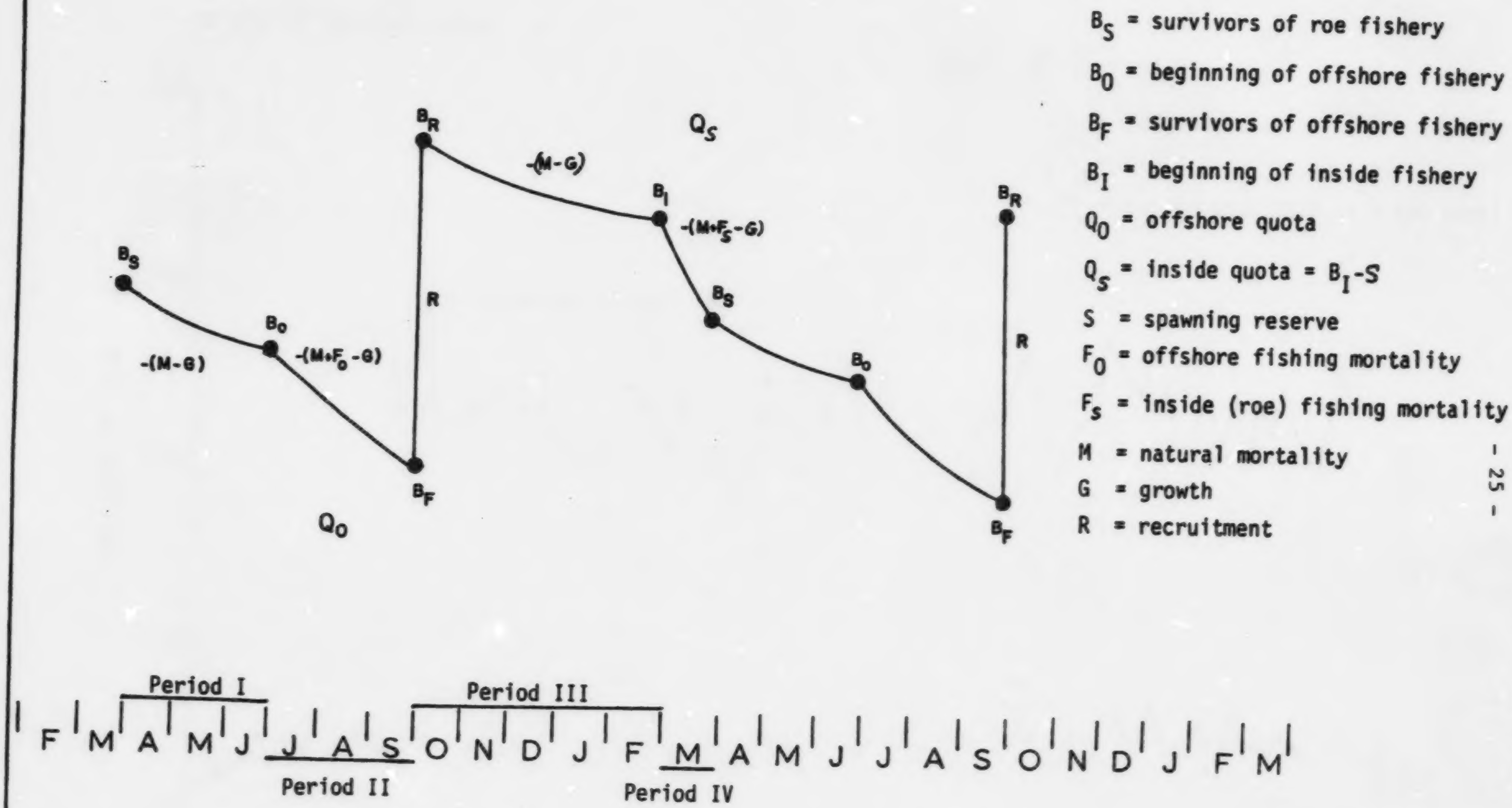
B_S
$-(M-G)$
B_O
$-(M+F_O-G)$
B_F
Q_O
R
B_R
$-(M-G)$
Q_S
B_I
$-(M+F_S-G)$
B_S
B_O
B_F
R
B_R
B_S = survivors of roe fishery
B_0 = beginning of offshore fishery
B_F = survivors of offshore fishery
B_I = beginning of inside fishery
Q_0 = offshore quota
Q_S = inside quota = B_I-S
S = spawning reserve
F_0 = offshore fishing mortality
F_s = inside (roe) fishing mortality
M = natural mortality
G = growth
R = recruitment
Period I
Period II
Period III
Period IV
F M A M J J A S O N D J F M A M J J A S O N D J F M

Figure 1. Basic time periods, rates, and biomass levels for herring harvest simulation.

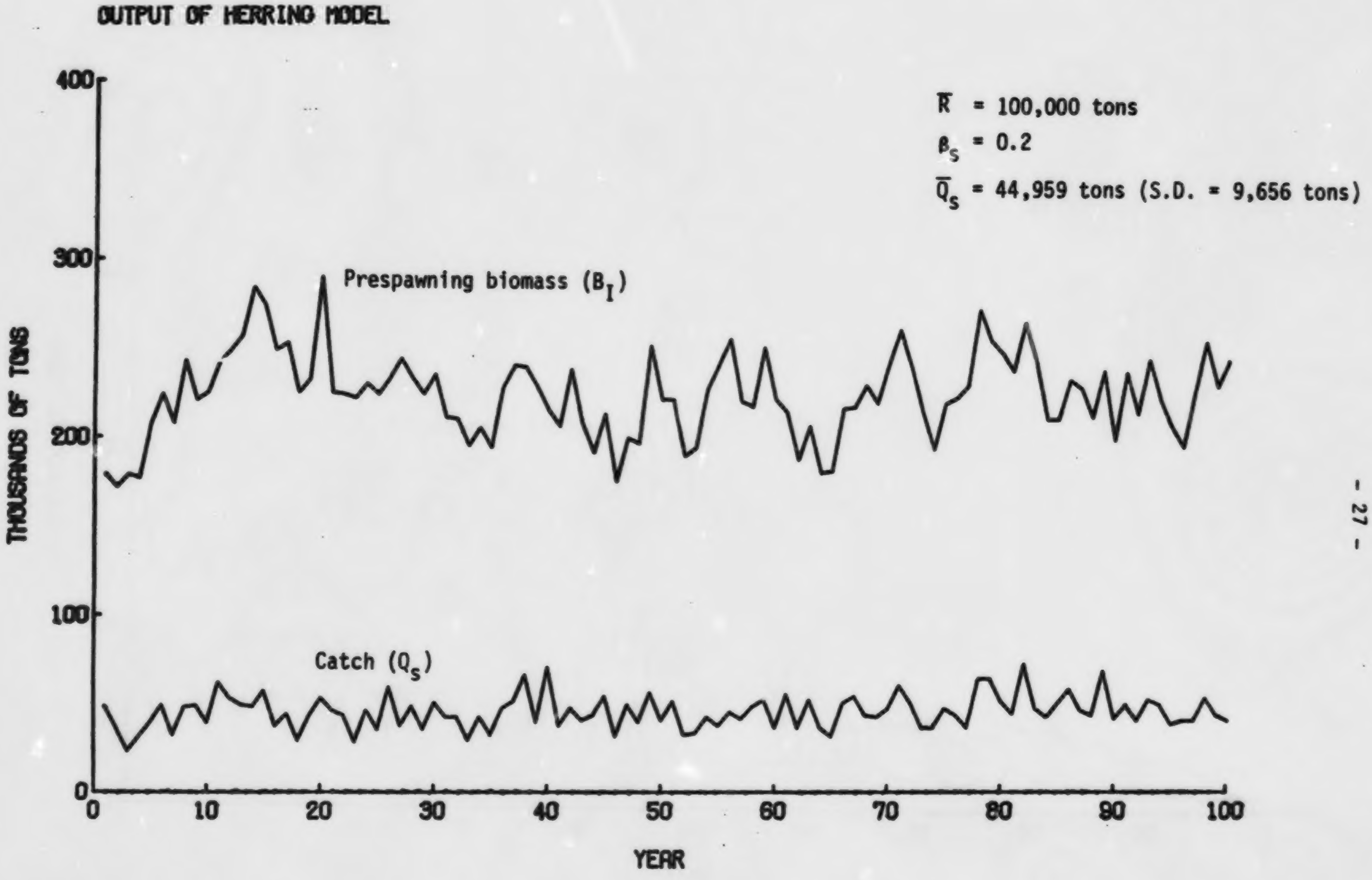

Fig. 2. Yearly catch and abundance of herring simulated by HMODEL; harvest rate is 20% of prespawning biomass.

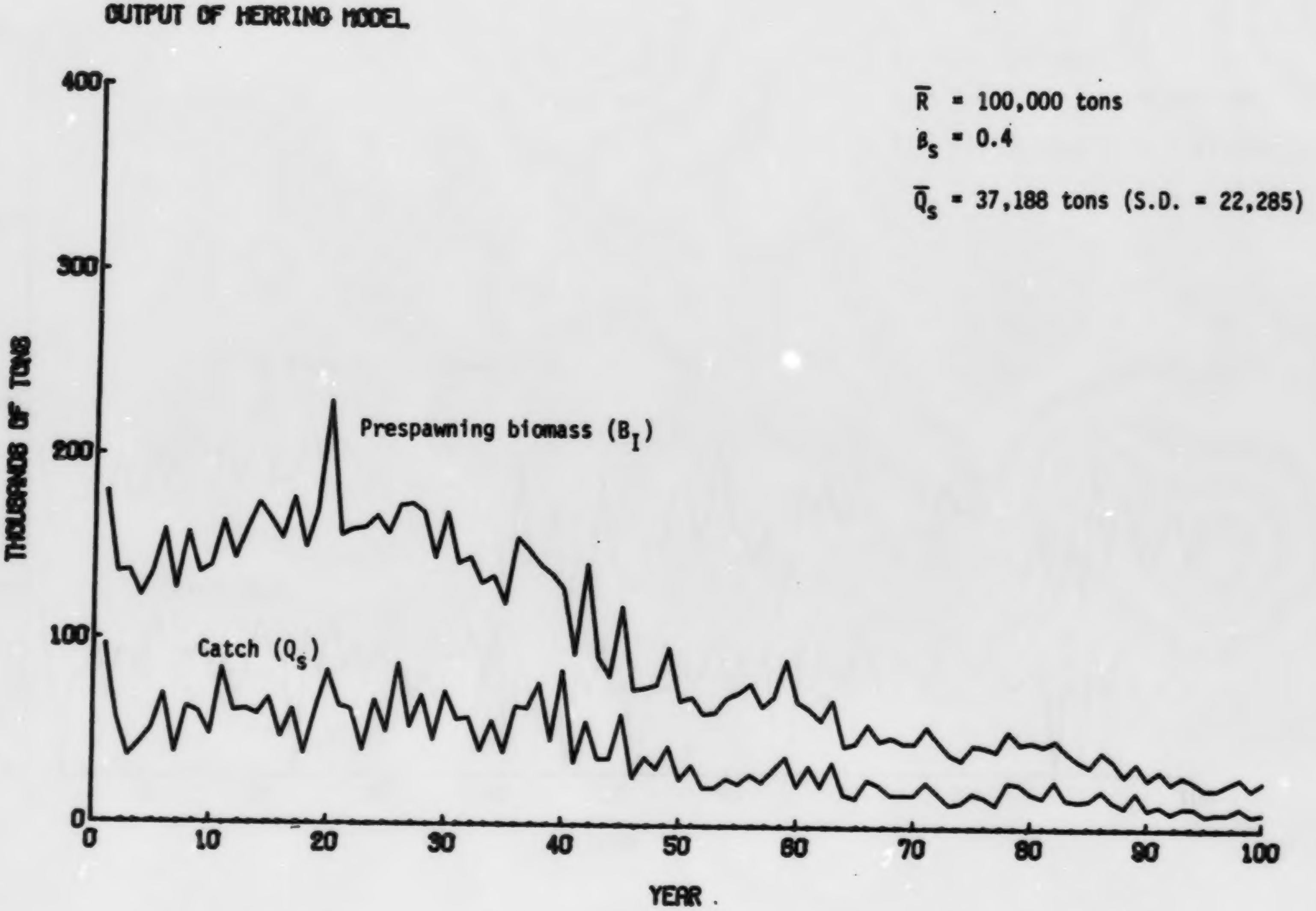

Fig. 3. Yearly catch and abundance of herring simulated by HMODEL; harvest rate is 40% of prespawning biomass.

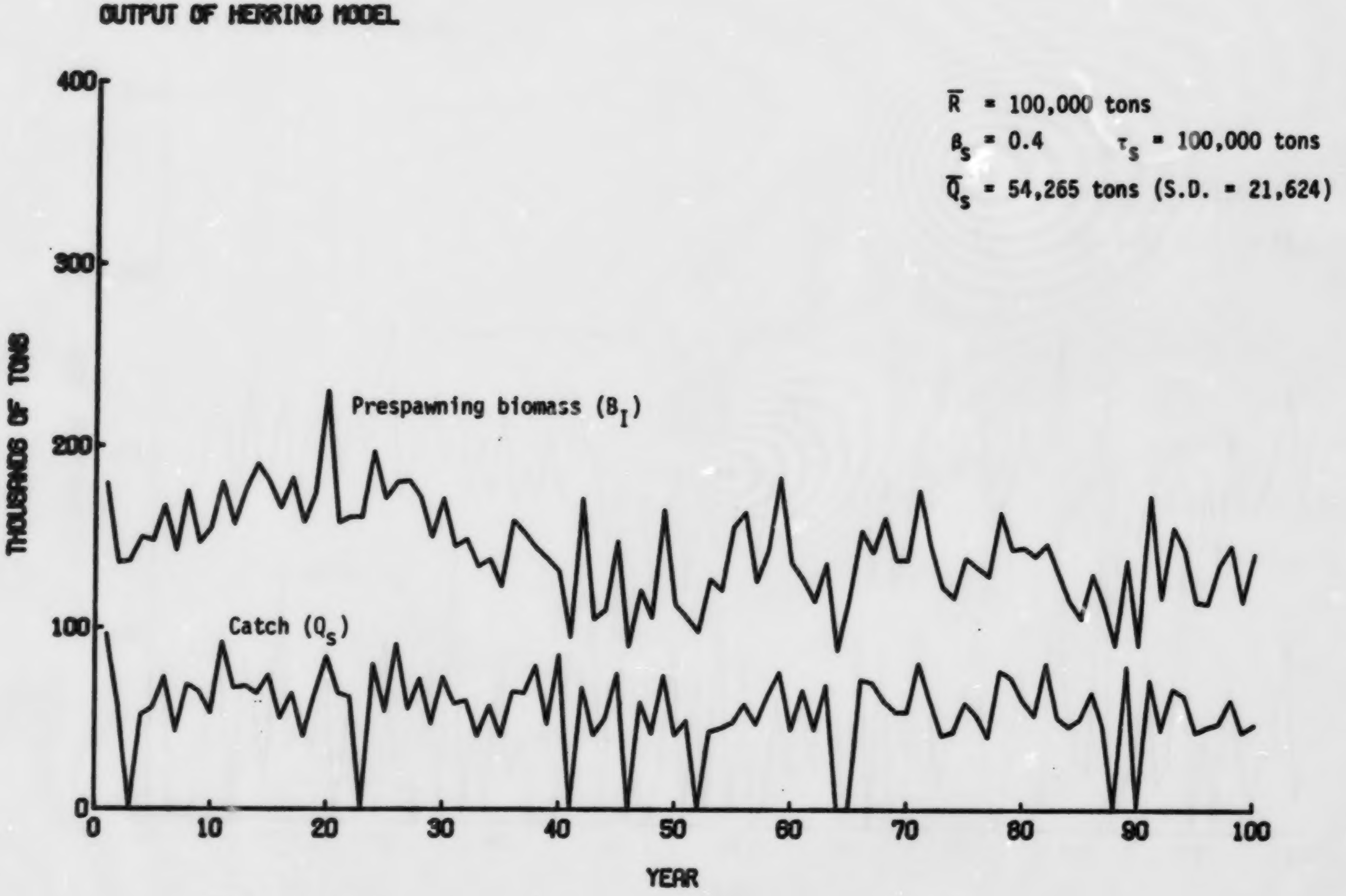

Fig. 4. Yearly catch and abundance of herring simulated by HMODEL; harvest rate is 40% of prespawning biomass if the biomass exceeds 100,000 tons, and 0 if biomass is less than 100,000 tons.

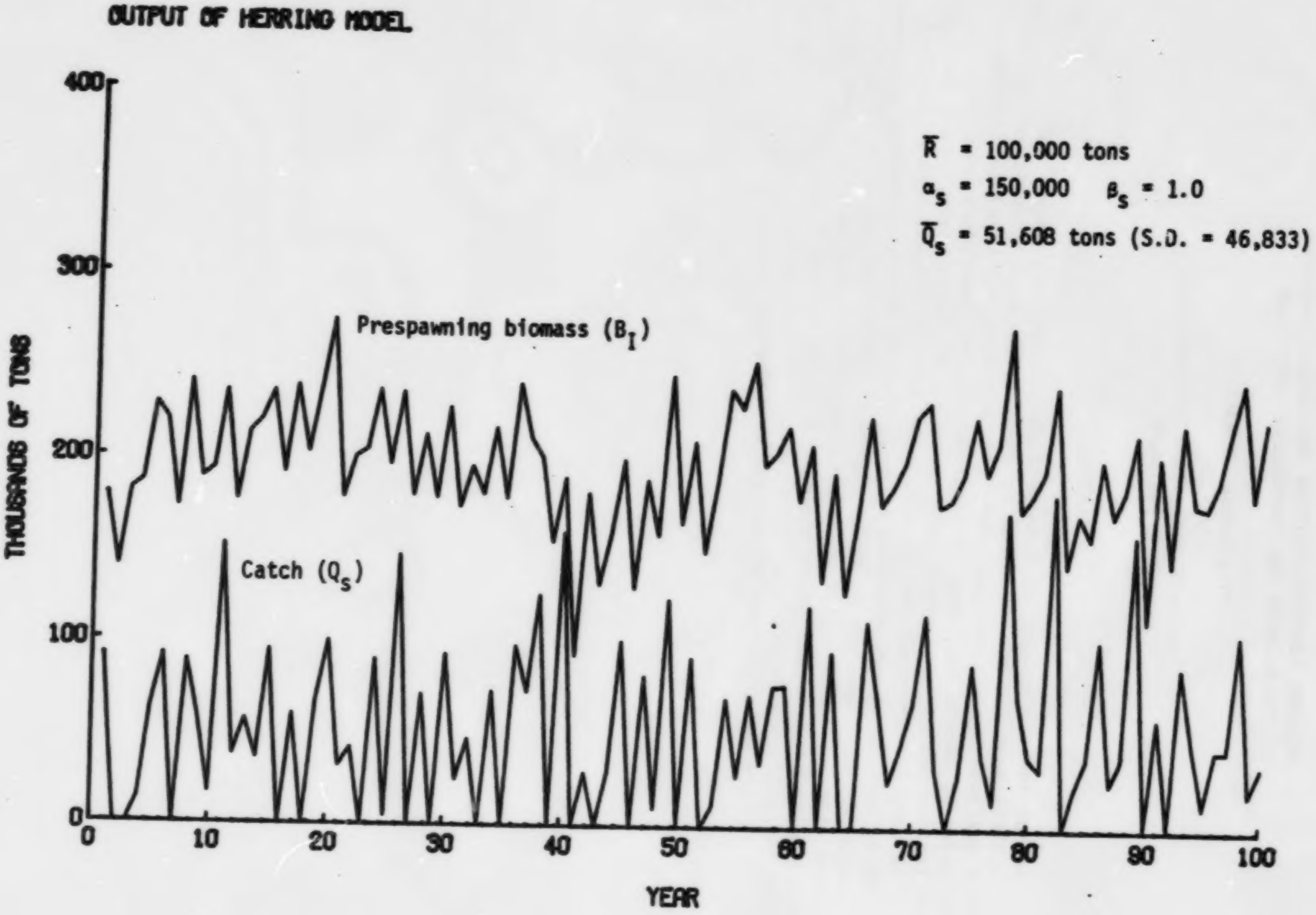

Fig. 5. Yearly catch and abundance of herring simulated by HMODEL; harvest rate is all biomass that exceeds a 150,000 tone spawning reserve.

SAMPLING DESIGN FOR BRITISH COLUMBIA HERRING ROE STOCK ASSESSMENT AND MANAGEMENT

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ABSTRACT

One sample per boat of 100 fish each is presently taken in the herring roe fishery based on analyses by Humphreys and Hourston (1978). Re-analysis of this data employing both two- and three-stage sampling designs indicated that individual samples of about 50 aged fish should be taken per boat or load. Since about 33% of these fish were unageable the optimal sample size really approximated 75 fish per load. It was demonstrated that a sampling intensity of 10% is sufficient to estimate the proportion of age 3 and 4 fish with 95% confidence intervals of 5% of the mean. On the other hand, even complete sampling of the population will not achieve this level of precision for age 7 and 8 fish. An examination of the sampling expenditure in relation to the accuracy of the estimates is required to determine the most cost effective sampling intensity to utilize on a routine basis.

SESSION III:

PRE-FISHERY STOCK ASSESSMENT TECHNIQUES

THE RELIABILITY OF HYDROACOUSTIC ESTIMATES

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I don't want to even pose as an "expert" on this subject, but perhaps by making some remarks about some of the factors the whole topic can be opened for discussion.

The reliability of hydroacoustic estimates will be affected by the variance of the density estimates and by the degree to which some basic assumptions are met. The assumptions are that:

1. Calibration is accurate, and the sounder and integration system stable.
2. The target strength values used accurately reflect the actual *in situ* values.
3. The species composition of each concentration is known.
4. All herring are fully "visible" to the sounder, and lie within the integrator's operating range.
5. All of the stock of interest is within the survey area at the time of the survey.

I would like to point out now that only the first two assumptions are specific to hydroacoustics, while the last two apply equally to any survey method, and furthermore, that even the first two assumptions have their parallels in other methods. For instance in hydroacoustics target strength is the major "scaling factor" in the conversion of relative to absolute estimates, while in swept volume trawl surveys the catching coefficient of the net is the scaling factor - and is as hard or harder to estimate.

If the basic assumptions are assumed to be met, then the accuracy of the estimates will depend on the relative variances of the individual density estimates. The variance varies inversely with the number of density estimates, and directly with the range of these estimates. Hydroacoustic surveys are characterized by large numbers of individual estimates - perhaps 120 per day on the basis of an estimate per mile at 9 knots. On the other hand density estimates of schooling fish typically cover a very wide range, of at least 3 and sometimes 4 orders of magnitude. It is not expected, therefore, that variance estimates are often large.

Another problem is how to estimate the variance of an obviously non-random distribution (a) where the points are taken serially along a track-line, (b) in which consecutive transmissions may be correlated in the sense that they measure the density in partially overlapping volumes of water, (c) show a degree of contagiousness (a large or small point estimate is likely to be followed by several estimates of similar size, and (d) which shows some dependence on the type of area (depth, bottom topography, etc.).

Several methods of estimating variance have been tried (Table 1). These include the simple method based on the assumption of a normal distribution used by Forbes and Nakken (1972), a method for when a degree of autocorrelation is present proposed by Bayley and Hammersley (1948), and a method applicable to cluster analysis put forward by Hansen, Hurwitz, and Madow (1953). The variance from the simple random distribution method tends to be biased low (Shotton and Dowd 1975), while that from the theoretically more appealing cluster analysis which considers both within and between transect variance should be larger. The cluster analysis method however does not appear reliable if there are only 2 or 3 transects, or if the transects have the same means and number of observations. In such cases the estimated variance appears unduly low and may approach zero. No method at present appears entirely satisfactory. Perhaps the best that can be said is that the variance calculated will be indicative of the general level that can be expected. For this purpose the simple random distribution method may be adequate.

The relative variance of the various herring concentrations were of the same order on all 3 cruises, and obviously dependent on the number of observations. The values ranged from a low of 0.095 to a high of 0.749. For hake and rockfish the relative variance tended to be smaller, varying from 0.093 to 0.521. This reflects the shorter range of density estimates found in hake and rockfish concentrations than in herring concentrations.

The accuracy of hydroacoustic estimates will depend not only on the relative variance but also on how well the four basic assumptions are fulfilled.

1. The system is accurately calibrated and stable. This is a very important factor and one which until the last 2 or 3 years was a major problem. It is now considered to be overcome. This was accomplished by changing from a good production model commercial sounder to one designed specifically for echo integration, and by using the most sophisticated techniques and equipment available for calibration (i.e., those of the Applied Physics Laboratory of the University of Washington). Calibration and stability are now considered accurate to within ± 0.5 dB.

2. The target strength value used accurately reflects the actual *in situ* value. Target strength is the major "scaling" factor in hydroacoustic estimates. It depends on the type of fish, their size, the aspect angle, the depth, and perhaps also the depth accommodation history. *In situ* target strength measurements using the dual beam method require fish to be unschooled and distributed as single fish. This method also needs more elaborate equipment than we possess. By considering target strength per kilogram rather than per individual the spread in published values is reduced and seems to fall into two groups, one for fish with air bladders and one for fish without. The dependence on size is also reduced. For herring we use a value derived from the literature of -32.0 dB/kg. A decrease of 3 dB will result in a doubling of the biomass. Unfortunately, it is not inconceivable that a change of 1 or 2 dB could result from changes in aspect angle or water depth. Measurements of the target strength per kilogram are badly needed, either dual beam measurements of the back scattering from single fish, or measurements from known densities of caged fish. Measurements should be at different depths and also after simulated vertical migrations.

The next two assumptions are basic to any resource survey whatever the method.

3. The species composition of each major concentration must be known. Species biomass estimates from single species aggregations will obviously be more reliable than those from multi-species aggregations and more reliable than those for single fish aggregations from an area where such aggregations of more than one species occur. Species composition must be determined by fishing, reliance cannot be placed solely on the appearance of the echosounder records although this in many cases is a valuable guide and may serve to extend fishing based information. Habitat type may also serve as a clue to species identification, but fishing is required to establish such a relationship. The greater the diversity of habitat the greater the number of species likely to be involved and the less reliable will be the data on species composition for a given amount of fishing. On the west coast of Vancouver Island the species or species groups mainly involved are herring, hake and pollock, pelagic and semi-demersal rockfish, dogfish, and to a small extent eulachon. Hake and pollock can generally be separated by habitat and type of school - they are usually found as midwater layers in deep water. Herring and rockfish are found in shallower water (less than 100 fm) and are difficult to separate, although the latter tend to school more often over rough bottom. Dogfish are a problem. In spite of their often large size, as targets they are about 1/20 as strong as herring. Thus unless they are present in large dense schools, they may not be readily recognizable on the sounder.

4. The assumption that all herring are fully "visible" to the sounder presumes that the school is not disturbed by the passage of the vessel. Kjell Olsen in Norway has shown that herring, especially when they are in a shallow layer at night, avoid the approach of a vessel. They first swim ahead of the vessel and turn out of the path, and then as the vessel actually passes over them, dive steeply. Both effects result in an underestimate of biomass. The first obviously decreases the number of fish in the path of the vessel, the second presents a tilted aspect to the sound beam and so results in a smaller signal. Avoidance reactions have been noted to occur over 50 m from the vessel. Avoidance may not be as serious a problem by day when herring are in denser schools on or near the bottom in deep water.

5. All of the stock of interest is within the survey area at the time of the survey. This is an obvious assumption. Its effect is usually minimized by careful planning, particularly if prior information is available on the distribution of the stock. Included under this heading are the assumptions that migration into or out of the area does not occur, and that movement between different parts of the area during the course of the survey is minimal. Factors in this category proved a source of uncertainty in the west coast surveys. In 1980 there was an element of doubt about the outer boundary of the herring stock. Did herring extend any appreciable distance beyond the edge of the continental shelf? I now think it is unlikely that they do. The timing of the 1980 surveys was such that emigration was a factor in both September and November. In March the offshore migration of spawned-out fish was occurring at the time of the survey.

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Table 1. Estimates of relative variance for the major fish concentrations encountered off the west of coast of Vancouver Island in September and November, 1980, and March, 1981.

	GBR80-7 September			GBR80-8 November			GBR81-3 March					
	Concentration number	Number of observations	Relative variance (Random)	Concentration number	Number of observations	Relative variance (Random)	Concentration number	Number of observations	Relative variance (Random)	Number of transects	Relative variance (Cluster)	Relative variance (autocorrection Bayley and Hammersley)
Herring												
	Hel	27	.246	1	14	.512	1	30	.275	3	.140	.269
	2	10	.259	3	12	.747	2	72	.245	10	.216	.242
	3	34	.591	4	65	.197	3	6	.454	1	-	.423
	4	63	.164	5	29	.095	4	98	.128	9	.151	.129
	5	16	.158	6	10	.210	5	104	.155	12	.168	.154
				9	26	.310	8	14	.400	3	.400	.385
	7	11	.299	11	17	.269	9	13	.365	3	.223	.345
	9	11	.555	19	13	.458	11	8	.257	2	.025	.252
	10	13	.375	21	11	.421	12	16	.362	2	.064	.342
				22	18	.153	13	35	.311	4	.393	.302
	18	10	.226				14	9	.360	2	.207	.339
Hake and Rockfish												
Hake	1	15	.153	24	54	.151	B1	42	.258	5	.206	.254
	2	9	.521	25	30	.119	B2&3	56	.199	7	.259	.202
	3&4	155	.093	26	51	.128	B4	51	.199	9	.242	.194
	6	8	.176	27	43	.109	B5	11	.184	1	-	.182
Rockfish	1	8	.306	33	13	.435	B6	8	.124	2	.002	.123
							B8	17	.177	4	.262	.179

THE DISTRIBUTION & ABUNDANCE OF HERRING OFF THE WEST COAST OF VANCOUVER ISLAND IN THE 1980-81 SEASON

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I would like to give a brief review of the three offshore hydroacoustic herring surveys conducted in 1980-81 off the west coast of Vancouver Island. These cruises were in September and November, 1980, and March 1981. The periods were selected in an attempt to represent times when all stocks summering off the west coast would be present - September, when only west coast spawning stocks should be present - November, and when only non-spawners should be present offshore - March. In the last two periods additional surveys were carried out, in November in the Strait of Georgia, and in March on the spawning grounds in Barkley and Clayoquot sounds. This seemed like a neat package where the estimates from the later cruises when added together should approximate the estimate from the first cruise. The cruises had to be scheduled 12 months in advance and we could only hope the fish would cooperate! Unfortunately, they didn't very well.

I am going to review only the three offshore cruises. The Strait of Georgia survey was not only apparently too early but was also upset by a serious equipment loss. The Barkley and Clayoquot sounds survey results have not yet been completely analyzed. The west coast surveys extended from Estevan Point south to the Juan de Fuca Trench and out to the edge of the continental shelf. The cruises followed a pre-determined set of track lines (Fig. 1, 2) which varied only in minor detail from cruise to cruise. The lines were about 2-2 1/2 miles apart, as they were based on Loran A, lines were somewhat closer together offshore than inshore.

In September, there were estimated to be about 67,740 t of herring in the survey area (Fig. 3, 4). However, of this amount 8% (5,630 t)[1] occurred north of Amphritrite Point. The major concentrations lay along the 100 fm edge from the trench northwards to about the latitude of Pachena Point. In this area there were about 49,000 t, over 31,000 t (63%) south of the U.S.-Canada fishing boundary. Other, smaller concentrations occurred inshore on the southwest and southeast corners of La Perouse Bank (6,260 t), on Swiftsure Bank (2,720 t) and mixed with the main hake and pollock concentrations (3,840 t). In total about 34,000 t or about 50% of the herring located were south of the boundary. At the start of the survey an additional 10,500 t were located off Victoria.

In November (Fig. 5, 6) the herring biomass was estimated to be 53,700 t, 21% less than in September. Most of the herring (39,600 t or 68%) were found between the 100 fm edge and the 50 fm contour. Distribution had changed appreciably. Only 12,370 t (33%) were now south of the fishing boundary. The largest concentration (23,900 t) now lay north of the Nitinat Canyon and stretched inshore almost to the east end of the Finger Bank. Inshore the quantity of herring, especially on Swiftsure Bank had increased

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[1] Amounts are in metric tons.

(from 2,740 t to 9,110 t). Nearly all the herring inshore and offshore were again south of Amphitrite Point. Only 2,900 t was located to the north.

In March (Fig. 7, 8) only non-spawning fish were expected offshore. However, because herring move offshore so rapidly after spawning a large proportion of the fish encountered were spent and recovering. On this survey, as would be expected, the biomass was smaller than on the other surveys. It amounted to 33,300 t, of which 17% was north of Amphitrite Point. Herring were spread out over a much wider area both north and south of this Point in March than on the preceding two surveys. The major concentration was still between the 50 and 100 fm contours, but formed an almost continuous band from the trench north to Estevan Point. Offshore there were estimated to be 5,310 t (31%) south of the fishing boundary, 6,550 t (38%) north of the boundary to Amphitrite Point, and 5,675 t (34%) north of this point. More herring were found inside the 50 m contour than on earlier cruises. There were 11,580 t north of the boundary and 4,195 t to the south. The largest concentration in March was on Swiftsure Bank (12,300 t), about 2/3 on the Canadian side.

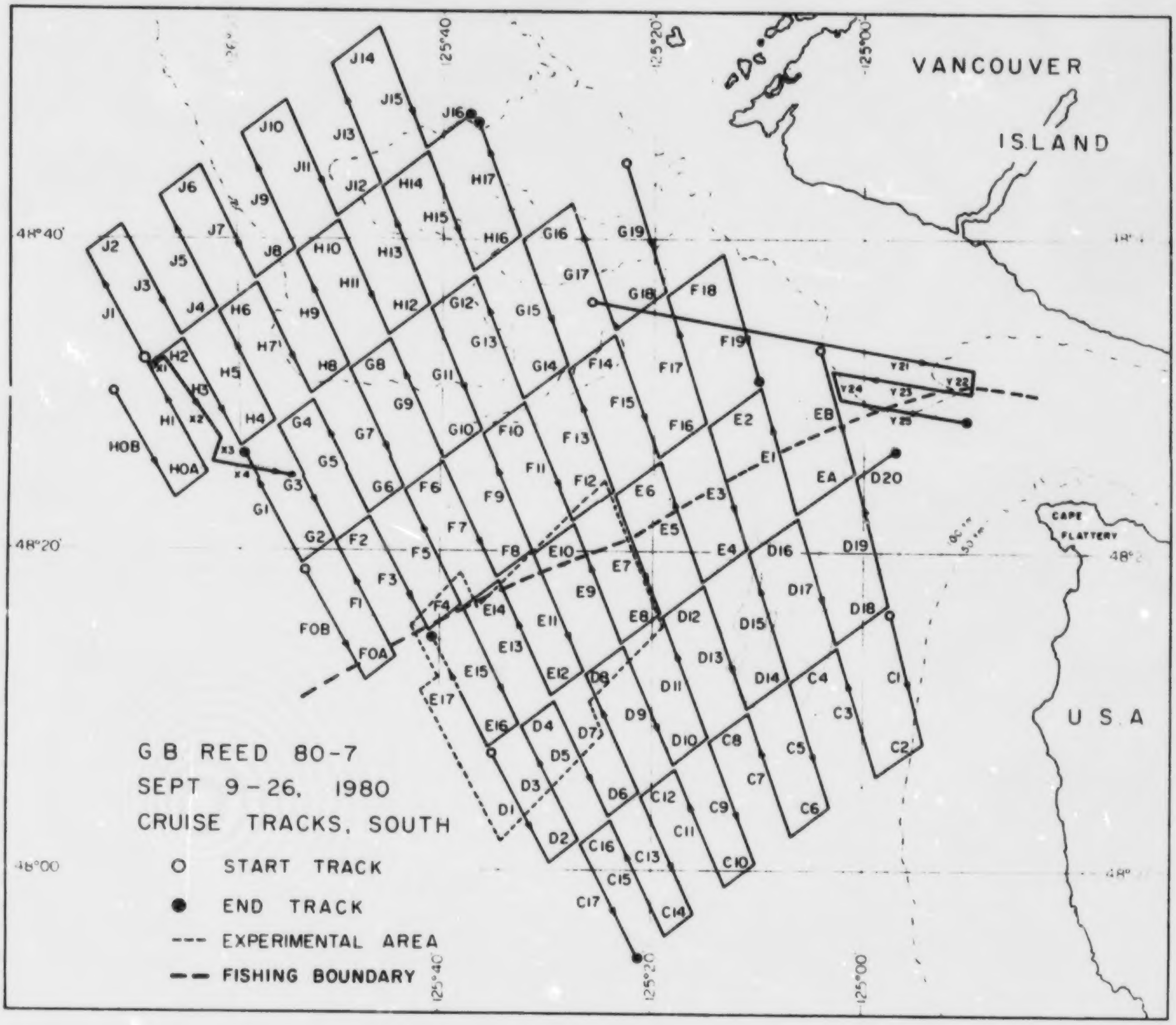
GB REED 80-7
SEPT 9-26, 1980
CRUISE TRACKS, SOUTH
○ START TRACK
● END TRACK
--- EXPERIMENTAL AREA
— — FISHING BOUNDARY
VANCOUVER
ISLAND
CAPE FLATTERY
USA
48°40'
48°20'
48°00
125°40
125°20
125°00
J1 J2 J3 J4 J5 J6 J7 J8 J9 J10 J11 J12 J13 J14 J15 J16
H0A H0B H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16 H17
X1 X2 X3 X4
G1 G2 G3 G4 G5 G6 G7 G8 G9 G10 G11 G12 G13 G14 G15 G16 G17 G18 G19
F0A F0B F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19
EA EB E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17
Y21 Y22 Y23 Y24 Y25
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17 D18 D19 D20
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17

Fig. 1. Cruise track lines south of Amphitrite Point.

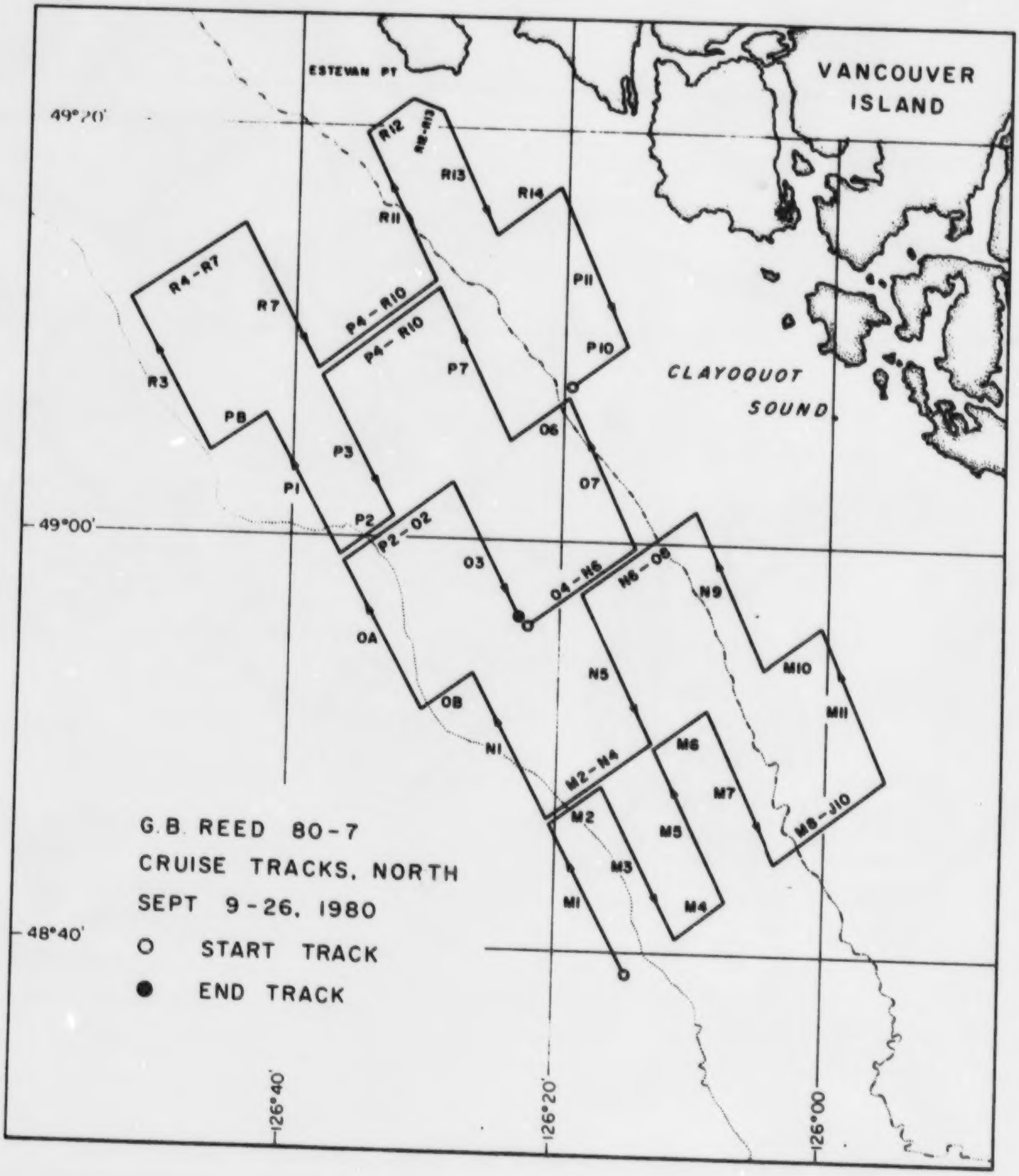

Fig. 2. Cruise track lines north of Amphitrite Point.

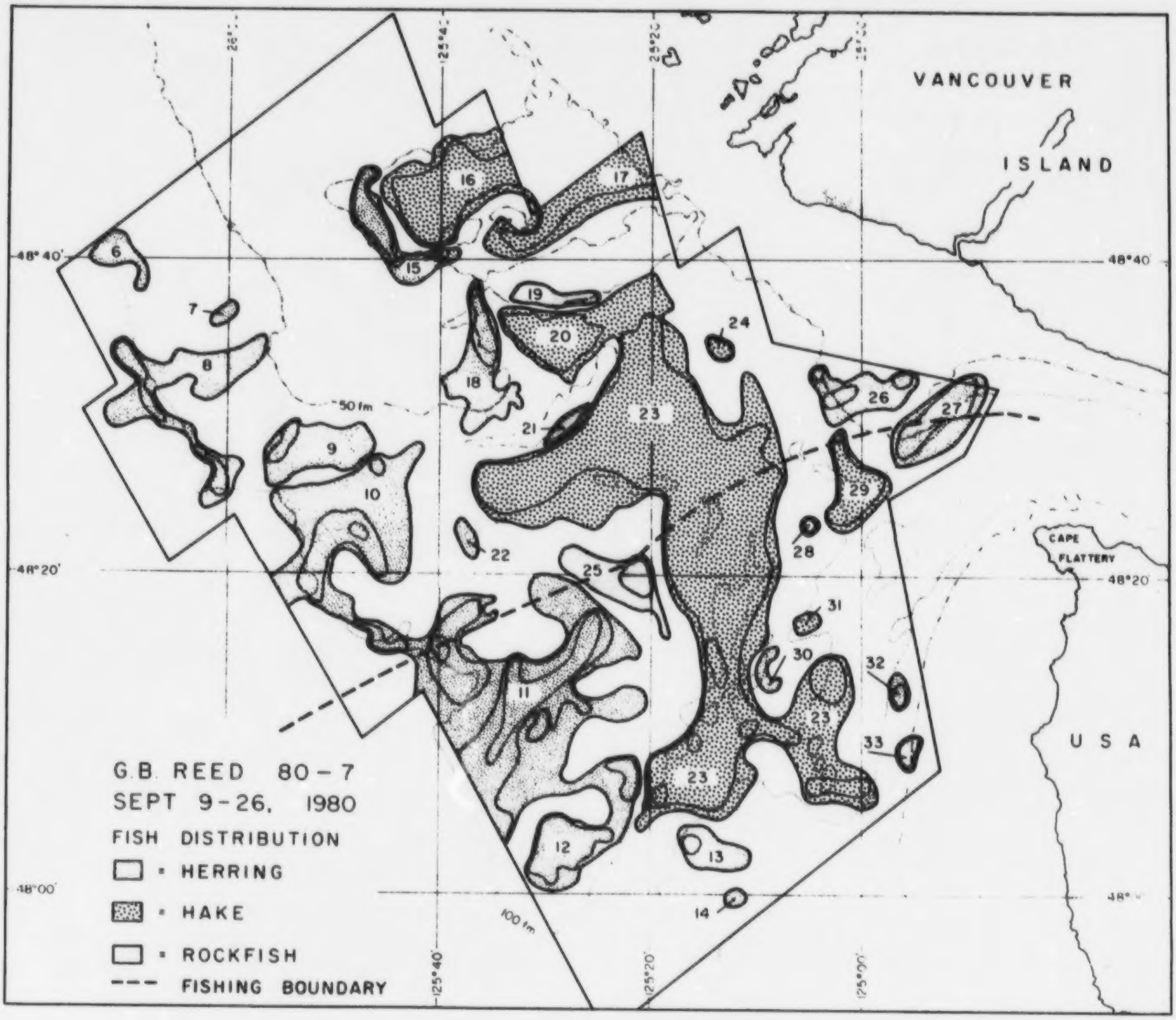

Fig. 3. Distribution of herring, hake, and rockfish concentrations south of Amphitrite Point. September, 1980.

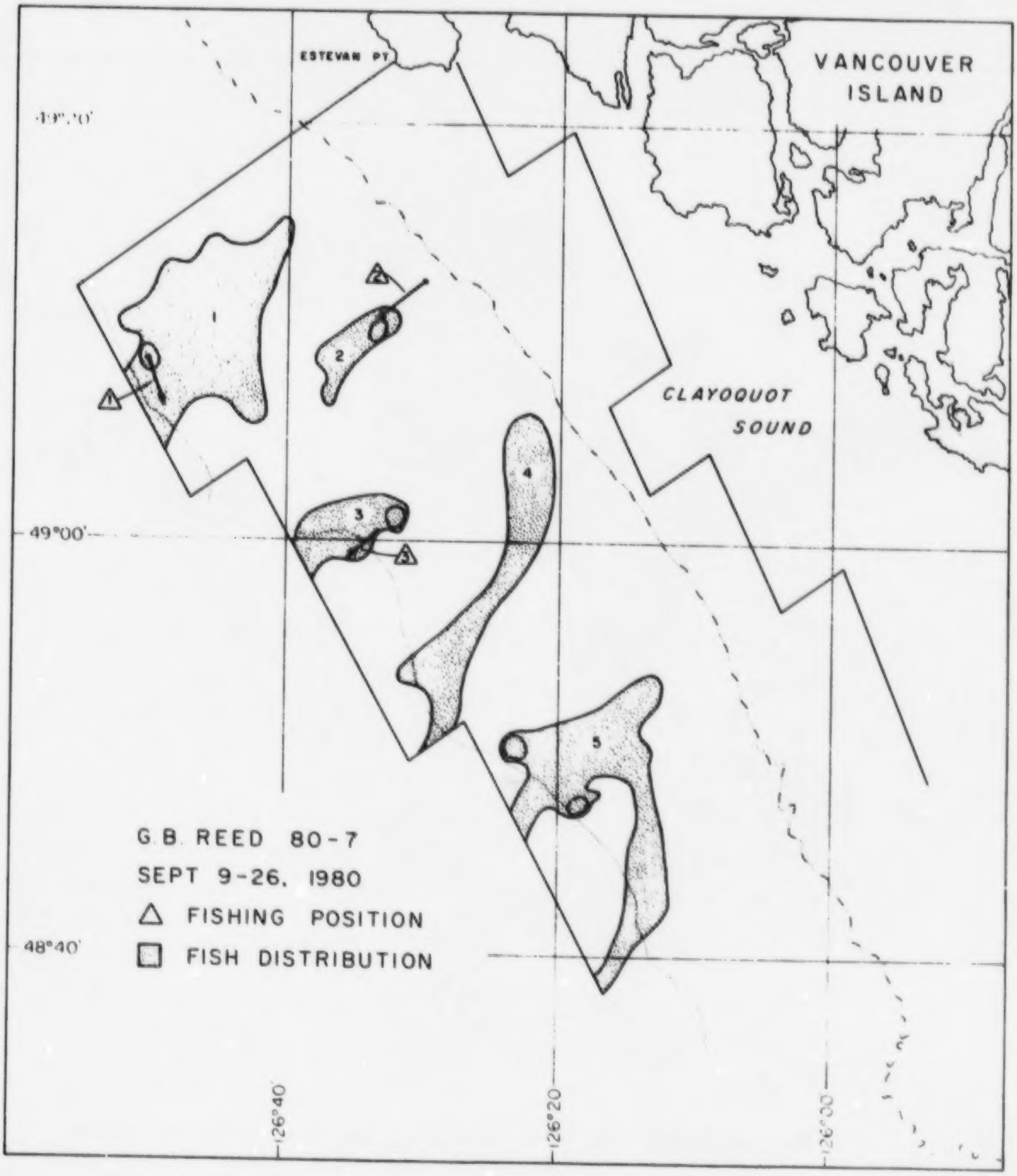

Fig. 4. Distribtuion of herring concentrations north of Amphitrite Point. September, 1980.

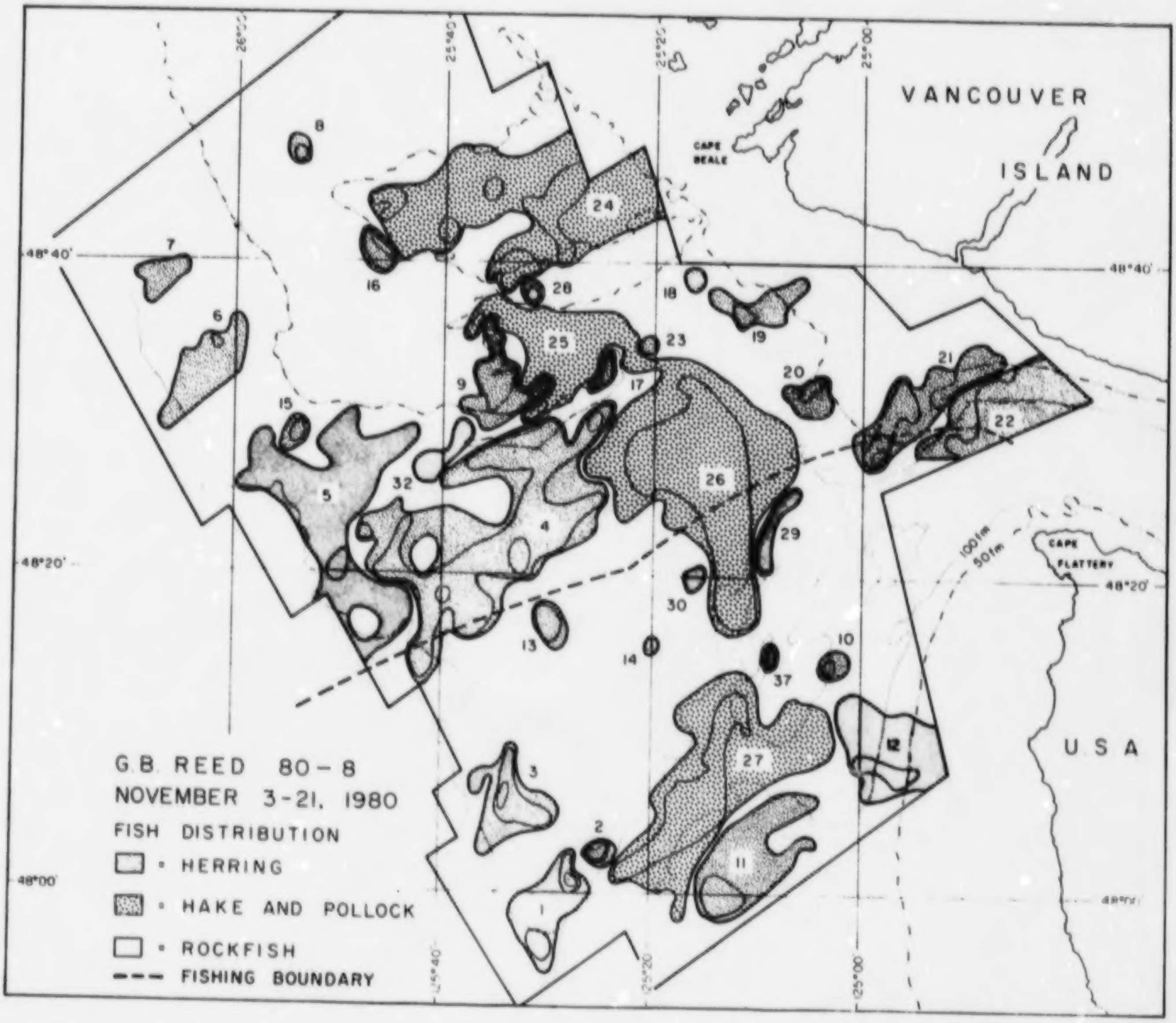

Fig. 5. Distribution of herring, hake, and rockfish concentrations south of Amphitrite Point. November, 1980.

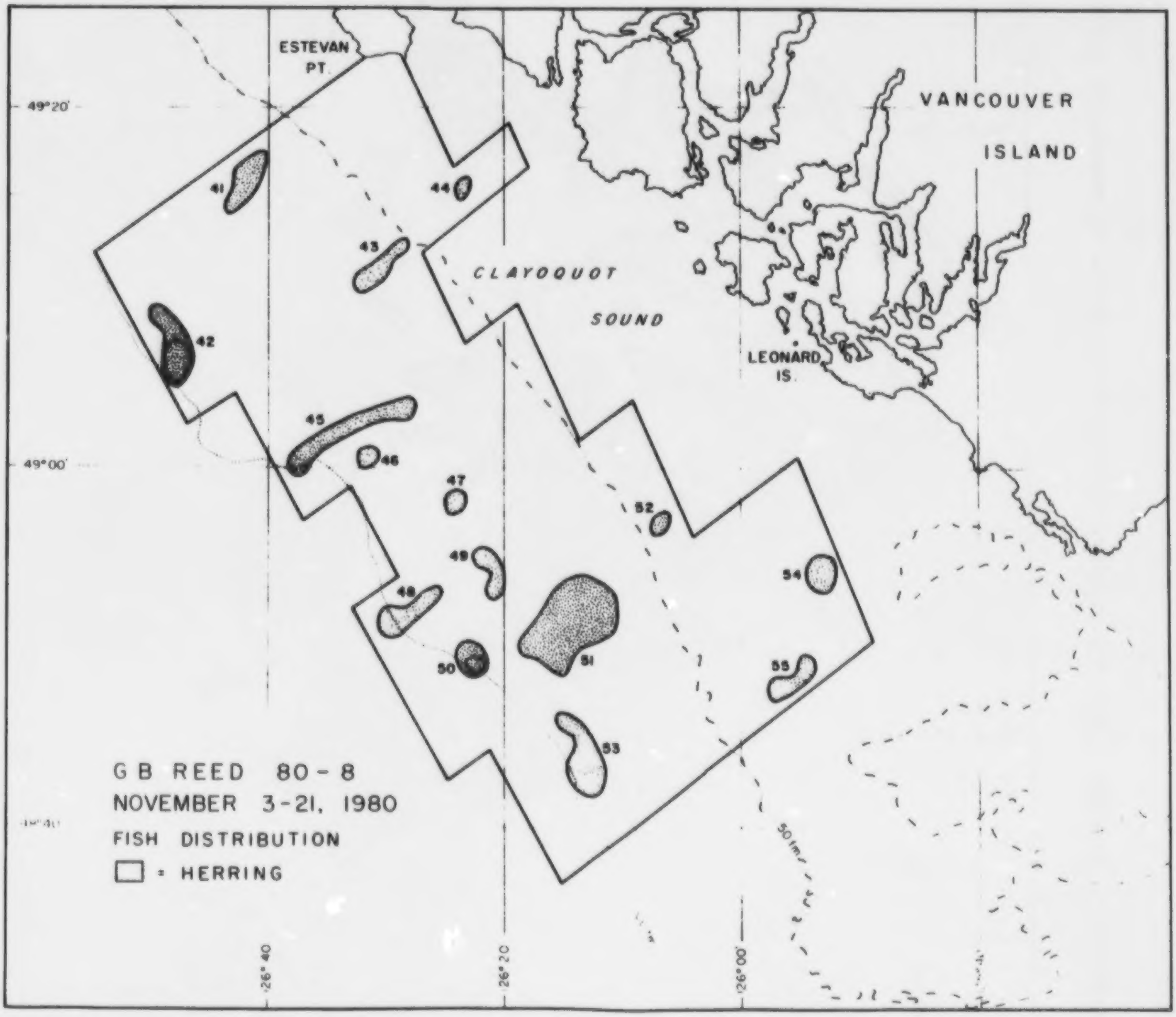

Fig. 6. Distribution concentrations of herring north of Amphitrite Point. November, 1980.

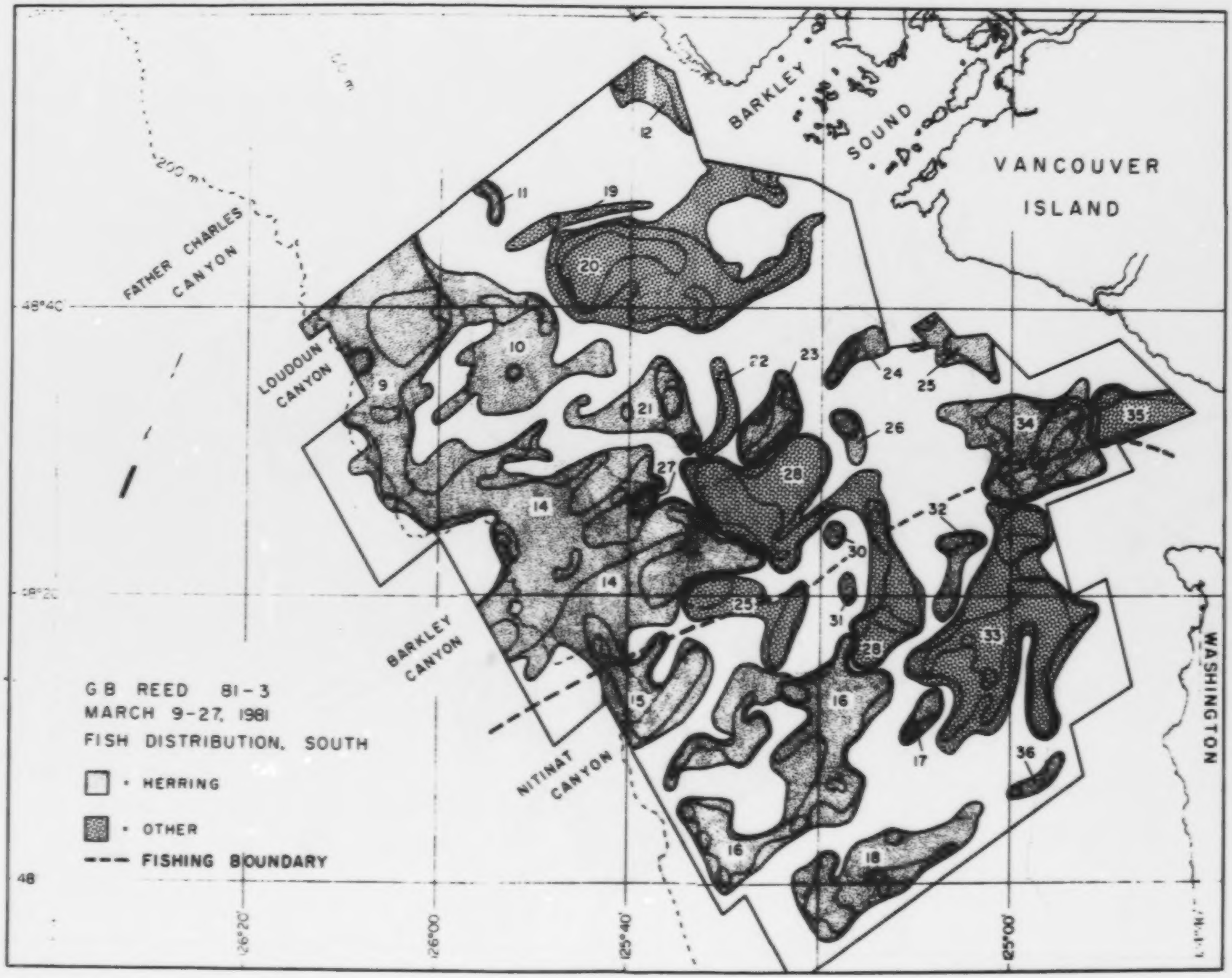

Fig. 7. Distribution of herring, hake, and rockfish concentrations south of Amphitrite Point. March, 1981.

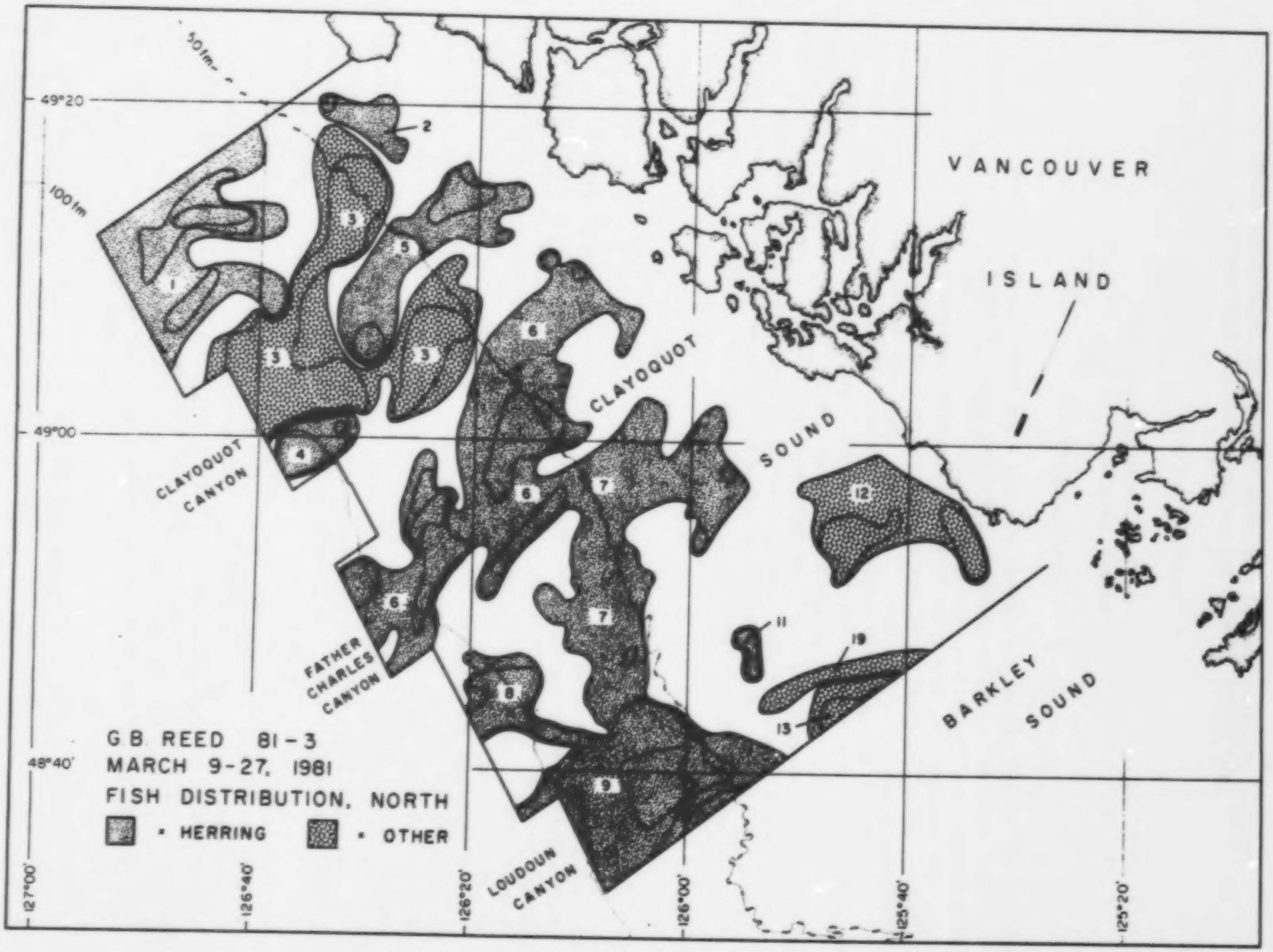

Fig. 8. Distribution of herring concentrations north of Amphitrite Point. March, 1981.

STOCK ASSESSMENT OF PACIFIC HERRING, *Clupea harengus pallasi* IN WESTERN ALASKA USING AERIAL SURVEY TECHNIQUES

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INTRODUCTION

Aerial surveys have been used in Alaska since the 1950's to monitor Pacific herring, *Clupea harengus pallasi*, spawning stocks. However, early surveys were of a qualitative nature and were not considered a reliable means of estimating actual herring abundance. With the rapid development of commercial herring fisheries for sac-roe in western Alaska in 1977, aerial surveys were looked to as the most practical, cost effective means available of assessing spawning populations of herring and managing the harvest. Although several problems remain to be solved, techniques have been developed which quantify data collected during survey flights so that population estimates can be made for herring spawning stocks. The purpose of this paper is to describe procedures used in gathering and analyzing data collected during aerial surveys, identify problems associated with conducting such assessments, and suggest ways for improving the reliability and accuracy of this technique.

METHODS

Most aerial surveys have been flown from fixed wing, single engine aircraft (e.g. Cessna 185, Piper Super Cub, etc.) at altitudes ranging from 91-457 m (300-1,500 ft) and speeds ranging from 148-260 km/hr (80-140 knots). In 1981 a few surveys were flown from a helicopter at similar altitudes and speeds of 167 km/hr (90 knots) or less. In general, weather permitting, an altitude of 457 m appears best for spotting and enumerating herring schools. Survey paths usually follow the coastline at distances of 1.9 km (1 mile) or less. However, portions of some flights are sometimes made further offshore to check for herring enroute to inshore spawning areas. Clear, calm weather conditions are best for surveying. Some surveyors also feel that times of low or ebbing tide also increase abilities to locate and enumerate herring schools. All surveyors wear polaroid sunglasses to reduce glare and thus improve sighting capabilities.

Standardized charts have been developed for all fishing districts and are used to record location, number and surface area of all observed herring schools. Several methods are used to estimate herring school area. A hand held viewing tube 216 mm (8.5 in) long with a grid of strings on one end has proved to be one of the simplest tools available to estimate areas of all but the largest schools. Reference lines on the grid can be calibrated for any altitude using the equation:

$$X = A\,(L/F), \text{ where}$$

X = ground distance represented by reference line on grid,
A = survey altitude,
L = length of grid reference line used, and
F = focal length of tube (216 mm).

Reference points on the ground (e.g., known distances between shoreline landmarks, vessels of known length, etc.) are also used whenever possible as aids in estimating school areas. To obtain estimates of extremely large schools, the time taken to traverse their length at a constant known airspeed has been used as a measure of distance. However, since actual aircraft groundspeed is generally difficult to determine, two transects are flown in opposite directions to obtain an average estimate of school length. In most cases, width of even large schools can be estimated using the viewing tube. Aerial photographs, used in the past to measure surface areas of selected schools, are not practical for in-season management when assessment results must be available soon after each survey has been completed.

To simplify school surface area calculations during surveys, a classification system has been developed which uses the following size categories:

1) small - surface area less than or equal to 50 m^2 (538 ft^2);
2) medium - surface area greater than 50 m^2, but less than or equal to 450 m^2 (4,844 ft^2);
    a) medium 1 - surface area greater than 50 m^2, but less than or equal to 254 m^2 (2,734 ft^2);
    b) medium 2 - surface area greater than 254 m^2, but less than or equal to 450 m^2;
3) large - surface area greater than 450 m^2.

After sufficient survey experience has been gained, surveyors have been able to quickly recognize and record small to medium sized schools without measuring lengths and widths of every school observed. However, attempts are made to obtain actual measurements for every large school sighted.

Spawning herring, observed as cloudy patches of milt, are enumerated and measured using similar techniques. However, since schools are not usually visible and milt is widely dispersed by water currents, spawning patches are reported in terms of linear km (or miles) with a subjective rating of spawning intensity (e.g. light, medium, heavy, etc.).

Data obtained during surveys are expressed in terms of a relative abundance index (RAI) for each flight and census area. This index is obtained by expressing school surface areas in relation to a "standard school" of 50 m^2 (e.g., each small school = 1 RAI unit; each medium school = 5 RAI units; each large school = [actual surface area/50 m^2] RAI units).

Estimates of herring population size, expressed as metric tons of herring, are obtained using conversion factors calculated from results of purse seine test sets conducted in conjunction with aerial surveys. Attempts have been made to capture entire schools (or estimated proportions of schools) after their surface area had been estimated from the air. A total of 12 data points are now available which suggest that tonnage per unit surface area decreases in shallow water (Table 1). Although detailed hydrographic charts are not available for western Alaska coastal waters, tonnage estimates for the Togiak fishing district during 1981 were made using conversion factors of 1.2 or 2.4 mt/RAI unit in areas of known shallow (3 m or less) or medium

(3-6 m) water depths, respectively, and 3.4 mt/RAI unit in all other areas. These conversion factors, based upon information available from the period 1978-1980 (nine data points), have decreased with the addition of three data points during 1981.

To obtain annual population estimates, peak daily tonnage estimates obtained for each fishing district during a season are used as minimal estimates of herring abundance. In Togiak District, two abundance peaks usually occur each season, corresponding to the arrival of old, return spawners (age five and above) and young, newly recruited spawners (age four and below) (Fig. 1). Annual estimates are modified and corrected during and after the season based upon changes in herring age composition and occurrence of other schooling fishes (e.g., boreal smelt, *Osmerus mordax*, capelin, *Mallotus villosus*, etc.) as determined from test fishing and commercial catch sampling.

DISCUSSION

Various problems still exist in using aerial surveys to assess spawning herring abundance. Survey coverage has often suffered from poor weather conditions, turbid water, and lack of sufficient funding. Conversion of RAI estimates to actual tonnage figures is hindered by the small available data base, lack of reliable hydrographic charts for all fishing districts, and limited knowledge concerning schooling behavior of herring in relation to physical (e.g., water depth, tide stage, etc.) and physiological (e.g., sexual maturity, body size, etc.) factors. Concentrations of spawning herring, although recorded during surveys, usually cannot be used in RAI or biomass calculations unless actual herring schools can be seen. Presence of other schooling fishes, unless confirmed through test fishing or catch sampling, can bias herring abundance estimates upwards. Interpretation of aerial survey data is difficult without knowledge of herring movement patterns prior to, during, and after spawning. Although seasonal changes in herring age composition and gonad maturation can be used to make some adjustments in tonnage estimates, based upon inferences of entry and exit patterns of herring, only peak seasonal estimates can be used for most fishing districts to avoid multiple counts of the same schools. Tagging programs or underwater biotelemetry studies could provide valuable information on herring movement patterns and behavior which could be used in interpreting survey data.

Although estimates of herring abundance based upon spawn deposition calculations or hydroacoustic surveys would be desirable for western Alaska spawning herring stocks, logistic difficulties, and costs have thus far precluded their development and use. Therefore, in spite of inherent problems recognized in using aerial surveys to assess herring stocks, this technique remains the most practical, cost effective means of managing Pacific herring stocks in the vast, remote reaches of western Alaska.

Table 1 . Conversion estimates (metric tons of Pacific herring per 50 m^2 school surface area) obtained from test purse seine fishing, Togiak District, Alaska, 1978-1981.

Year	Water Depth (m)	Biomass per RAI unit (m.t./50 m^2)	
1981	2	1.1	Catch landed
1980	3	1.2	Catch landed
1980	5	1.1	Catch landed
1980	5	1.2	Catch estimated in net
1979	6	2.4	Catch landed
1980	6	3.0	Catch estimated in net
1980	6	2.6	Catch estimated in net
1981	6	1.7	Catch landed
1980	8	1.6	Catch estimated in net
1981	8	4.0	Catch landed
1978	?	6.7	Catch estimated in net
1978	?	11.0	Catch estimated in net

Mean all estimates = 3.1
Mean estimates at 2-3 m = 1.2
Mean estimates at 5-8 m = 2.2

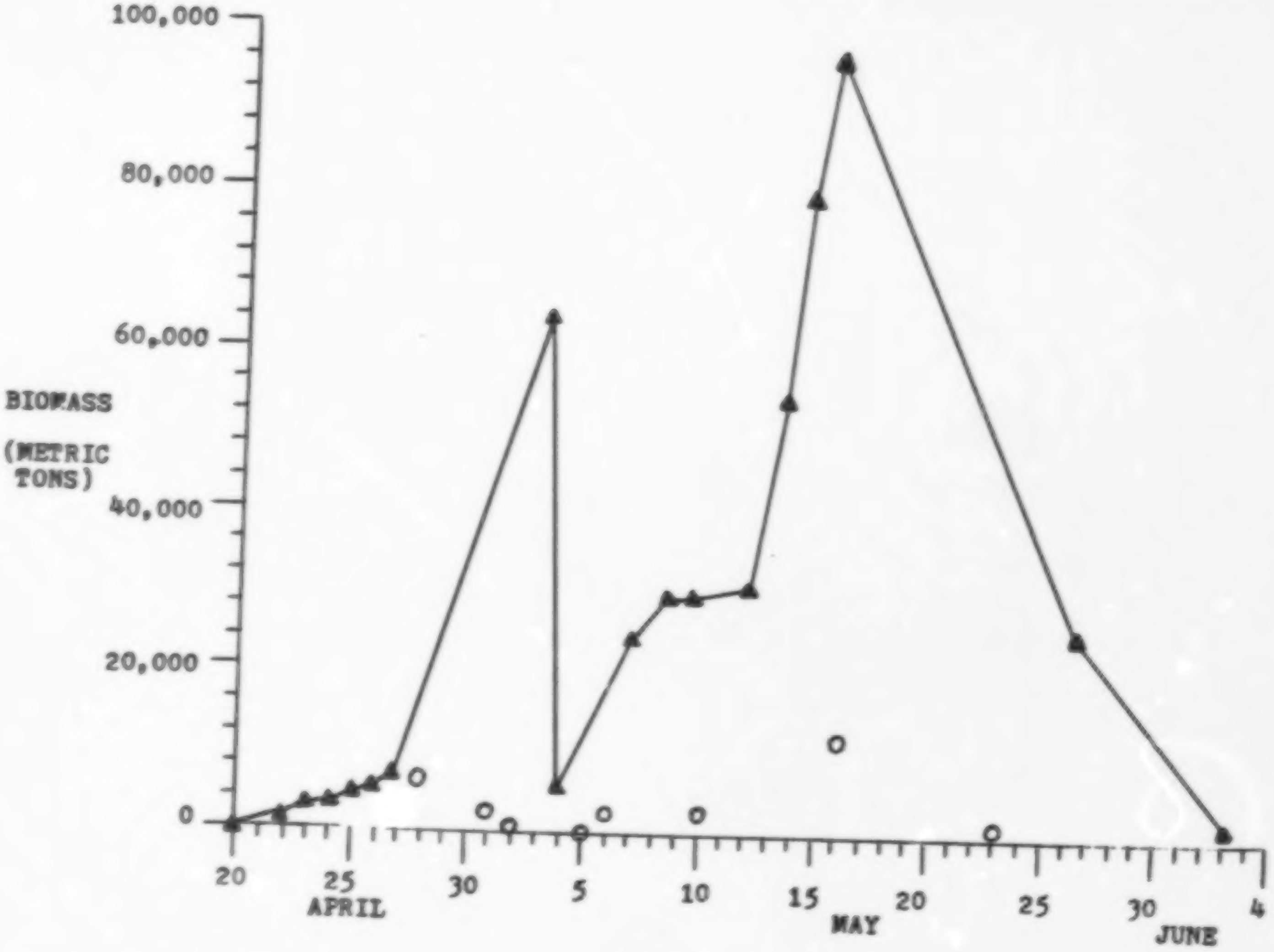

Fig. 1. Metric tons of Pacific herring present on spawning grounds of Togiak fishing district, Bristol Bay, Alaska, 1981, as estimated by aerial surveys. Darkened triangles (▲) indicate surveys when conditions rated fair to excellent. Open circles (O) indicate surveys when conditions rated unsatisfactory to poor.

SESSION IV:

SPAWNING ECOLOGY; INNOVATIONS IN SPAWN SURVEYS

HERRING SPAWN SURVEYS IN B.C.

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Data collected from surveys of herring spawn has been used as an index of stock abundance since the late 1930's. Initially only accessible portions of the coast were surveyed. By 1955, surveys were conducted of most spawns and large scale maps were available for recording the precise location of spawns. The index of abundance of miles of spawn adjusted to an intensity of medium and corrected for variations in width proved insensitive to declines in stock abundance during the late sixties, although the number of records and observed length decreased quite dramatically.

In the early 1970's, attempts were made to derive direct estimates of spawners from survey data but there was little information available on the conversion of spawn survey data to numbers of eggs. In 1975, an investigation was begun on the possibility and potential of developing methods by which quantitative spawn survey data could be developed.

Several approaches were developed during the course of this investigation. The marine algae and sea grasses were to be mapped for major spawning grounds to facilitate the detection, recording, and assessment of spawn. The layer method of rating spawn density was developed to replace the quantitative intensity scale. From a collection of over 1000 spawn samples, empirical relationships correlating eggs per unit area with vegetation type, percent cover and layers of eggs were developed. (This data has been reworked by Schweigert and Fournier to develop a model that predicts egg numbers from these observable parameters.)

In the course of these investigations it was found that spawns extend deeper and are wider than had been suspected, and that the survey of deeper spawns is not amenable to grappling or other surface-based survey methods and that adequate data can only be collected by divers. Since all spawns cannot be surveyed by divers because of their wide distribution in time and place, a spawn survey manual was developed to help Fishery Officers in conducting better surveys and workshops were conducted to provide training in the execution of spawn surveys. Concurrently with the improved Fishery Officer spawn surveys, problem areas were surveyed by divers. This diver coverage was extended to about half of the coast in 1980 and further in 1981, when 172 km of spawn were surveyed.

While these diver surveys have been implemented, further work is being conducted on the precision and accuracy of spawn surveys. In 1981, studies were conducted at two sites in the Strait of Georgia and at four sites in the Queen Charlotte Islands, where data was also collected, for the first time, on the distribution of eggs on the giant kelp, Macroscystis.

The present status of spawn surveys and related research and development work is as follows:

1. Fishery Officers continue to survey all spawns on the B.C. coast, using the best available techniques as they are developed but still being mainly restricted to surface based surveys. It is considered important that this time series of data is maintained, especially since it is showing promise in population models such as that by Deriso.

   Field Services personnnel are also encouraged to implement diver surveys of spawns on a selected basis to survey spawns that cannot be surveyed adequately by traditional methods.

2. The mapping of the marine algae and sea grass on spawning grounds is nearly complete with 900 km of coastline mapped or being mapped.

3. The capability of spawn surveys to estimate egg numbers is being further developed and assessed.

4. Regional concerns about stock size and escapement are being addressed through sampling-type diving surveys of spawn.

5. The distribution of spawns for the period 1955 to 1980 is being gazeteered to answer concerns about whether gillnet fisheries on spawning grounds have impacted on the selection of spawning localities by herring and to provide planning and study groups with pertinent information for consideration of coastal development plans.

PRELIMINARY REPORT ON "ROE-ON-KELP" RESEARCH AT BRISTOL BAY, ALASKA

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University of Alaska
Juneau, Alaska

Alaska has in the past been involved in herring roe-on-kelp fisheries throughout the state. Roe-on-Macrocystis has been harvested near Sitka in the past but this fishery has been closed for several years. However, both Prince William Sound and Bristol Bay have very active roe-on-kelp fisheries. Prince William Sound has had a recent history of harvesting roe-on-Laminaria with the 1979 production being 472,000 pounds (Blankenbeckler, 1980). Only in the past few years has a similar harvest begun at Bristol Bay. From 54,000 lb in 1968 to 378,000 lb in 1981 (ADF&G 1981) the harvest has attracted an increasing number of participants each year. Last year (1981) 108 fishermen were harvesting spawn-on-kelp in the Bristol Bay area (ADF&G 1981).

Unlike most other roe-on-kelp fisheries the harvest at Bristol Bay focuses primarily on intertidal spawn on the rockweed, Fucus. Fucus is not normally considered to be a kelp since it is intertidal and relatively small compared to Macrocystis or Laminaria. The major source of income from herring at Bristol Bay is the sac roe fishery which accounts for about 95% of the revenue (McBride and Clarke 1979). However, the spawn-roe-kelp fishery is an important "cottage industry" with the majority of the permits being issued to local residents.

The Alaska Department of Fish and Game (ADF&G) in an effort to manage the roe-on-kelp fishery in Bristol Bay has contracted with the University of Alaska, Juneau to conduct research on the basic biology of Fucus in the Bristol Bay region.

ADF&G is currently using a management strategy that involves dividing the coastline into 11 "K" areas (McBride and Clarke 1979), (Fig. 1). When 10% of the estimated Fucus biomass has been harvested in a specific K area, the affected area is closed. Biomass of the Fucus plants in the past has been measured using a double random plot design. Transects are run at random points along the beach, and 1/4-m plots are measured at random along these transects from the upper littoral to the low water line. Percent cover and egg layers, if any, are estimated, and all the large Fucus plants are harvested for later weighing. Associated with the biomass estimates done in this manner are rather large confidence intervals that can be as much as ±500% of the estimate. These errors are probably due to: (1) missing of numerous small beds due to the random placement of transects, (2) transects occurring in a mud flat area devoid of Fucus, (3) placement of quadrats in the upper intertidal zones where Fucus plants never grow. It appears that the placement of transects should be confined to defined Fucus beds in order to reduce the error of the biomass estimates.

We devised during the summer of 1981 an alternate method that will correlate the biomass of the plants with percentage cover and depth of the plants. The procedure we propose is the following:

1. Fucus beds will be defined more precisley by use of existing infrared and visible light aerial photographs.

2. Transects will be located only in defined Fucus beds, and placement of quadrats will be limited to the area between the upper and lower limits of Fucus (approximately -1 to +2.5 m).

3. Using 1/4-m^2 quadrats the percentage cover of the plants will be estimated using a 25-point grid. The depth of the canopy will also be measured at these points. Depth is measured vertically from the top of the canopy to the rock substrate. All measurements will be made during the lower of the low waters.

4. Egg layers, if any, will be estimated.

A multiple regression of percentage cover and depth of the canopy on fresh weight gave a very good correlation which was signficiant at $p<0.05$ (Kendziorek, pers. comm.). We believe this method will prove to be a faster, easier, and more accurate biomassing technique for Fucus.

Apart from biomass estimates it is necessary to ascertain the normal growth rates of the Fucus plants. We have set up a number of experimental study areas in and near Metervik Bay (Areas K2 and K3). Growth rates of mature and young plants have been followed for one season. Preliminary data indicates an average growth rate in some areas of 5-10 cm per plant per season. Additionally, it appears from thinning studies that the plants remaining after a thinning grow faster than those in unthinned areas.

Several clearing studies have been initiated in which various size areas in the intertidal have been cleared by several different methods (e.g., burning, scraping, hand-picking). These areas are being monitored for species diversity, recolonization by Fucus, growth rates, and other parameters. Preliminary date indicates that Fucus is both the primary invader or pioneer plant and also the climax plant in the succession. There appears to be no serious competitor with Fucus from any other algal species in the Metervik Bay area.

Although we have initiated no formal studies on substrate preference, we have observed that Fucus germlings grow best when they grow initially in protected areas such as cracks in rocks or on the surfaces of barnacle shells. Fucus germlings need protection from grazers and from scouring by waves. Barnacles may be a major factor in Fucus survival at Bristol Bay since they afford such protection and because there are large sets of barnacles during the roe-on-kelp harvest. Factors which affect barnacle viability may have serious implications on the survival of the next generation of Fucus plants. Experiments are planned to assess the importance of the barnacles to Fucus growth and survival.

Experiments have also been initiated doing some subtidal survey work to determine the extent of spawning by the herring below the lowest low water line. Bristol Bay has predominantly a mud/silt bottom, and the entire bay is relatively shallow. Storms and winds are frequently creating considerable chop and turbidity. These conditions have precluded extensive SCUBA diving in this area and have contributed to the dearth of knowledge about the extent of subtidal herring spawn. However, two subtidal spawns were visited in the 1981 season.

A very large spawn occurred subtidally at Ungalikthuk Bay in early May. Here the spawn occurred on eel grass (Zostera sp.) only. The area of the spawn was about 6 km^2. It extended from the low water line to a depth of 3-5 meters. Although there were boulder patches containing stands of Laminaria scattered throughout the area, there were no eggs on any of the Laminaria fronds or any plant other than eel grass. Sampling was done by SCUBA divers at randomly placed quadrats throughout the spawn area. The data from this survey has not yet been put into final form.

A second major spawn occurred at Metervik Bay toward the end of May (1981). The area involved was 0.5-1 km^2. This spawn was mapped by towing SCUBA divers across the area. The spawn in this case was deposited primarily on Laminaria. A biomass estimate was precluded by storms.

Based on very preliminary data from the 1981 field season, we have made the following tentative conclusions and results:

1. We propose a new technique for assessing Fucus biomass.
2. We propose a modified management strategy that would allow almost total harvest of a Fucus bed followed by closure of that area until the understory plants have regenerated and reseeded the area. If 1981 growth rates were typical, closure would be for a time period of 2-3 year.
3. Fucus is the dominant intertidal algal species in Metervik Bay area.
4. Subtidal spawning may be more significant than previously thought. Although the commercial quality of such spawn may be inferior, the amount of the spawn may contribute significantly to the herring population in Bristol Bay.

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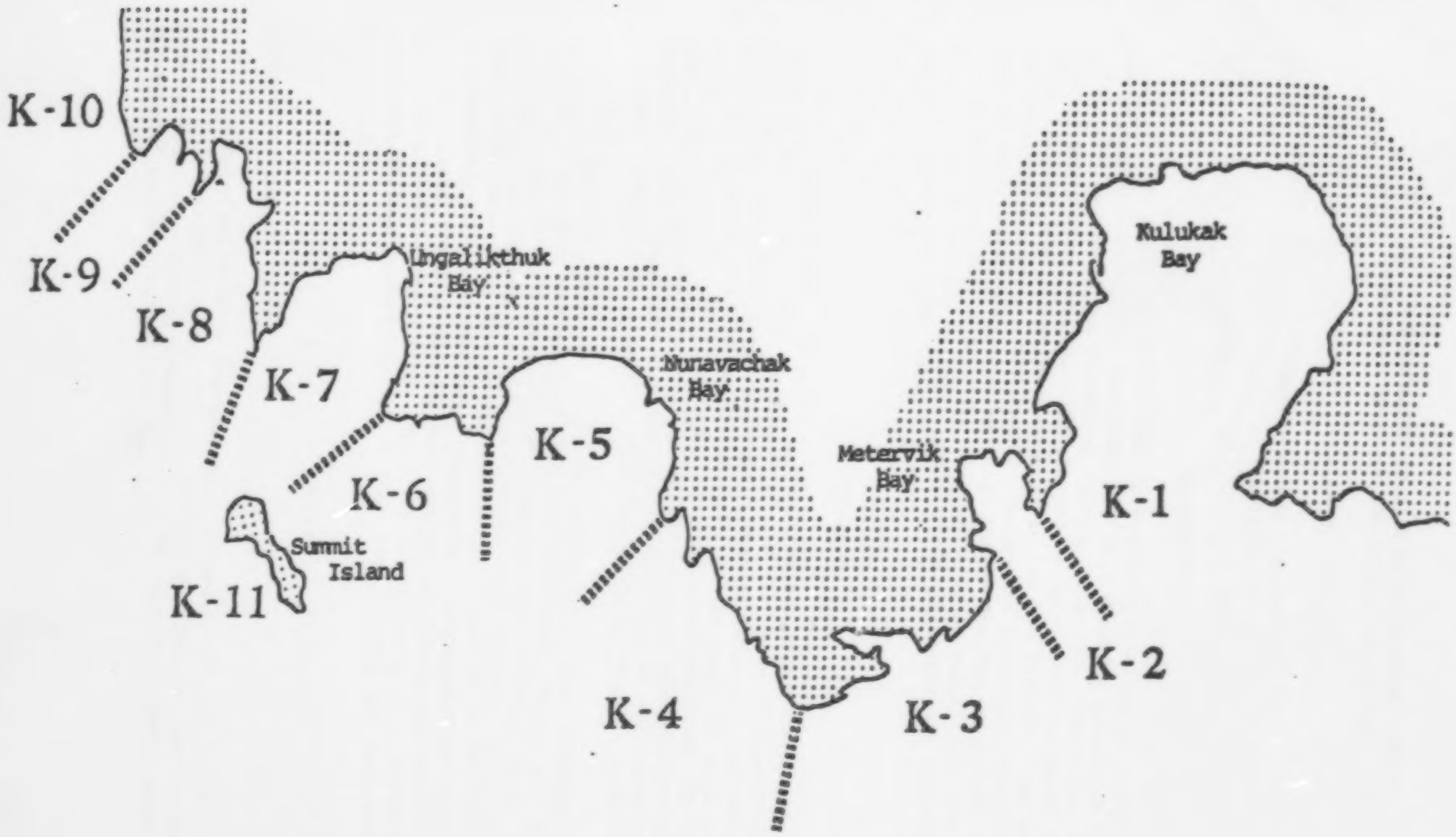

Figure 1. Herring roe-on-kelp management areas (K-1 through K-11), Bristol Bay.

OCEANOGRAPHY OF A HERRING SPAWNING GROUND AND ROE FISHERY IN THE STRAIT OF GEORGIA, B.C.

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INTRODUCTION

In March and April 1980, a preliminary study of oceanographic and water quality conditions was conducted at a spawning ground on the east side of Denman Island in the Strait of Georgia (Fig. 1). The object of the study was to investigate the possible changes in water quality due to fallout of dead herring from gillnets being used in the roe fishery. For example, decomposing carcasses could consume oxygen and introduce excess nutrients in bottom water, thus possibly 'souring' the ground for subsequent spawning. Since there are only a few data (Outram 1975) on temperature and salinity conditions at herring spawning grounds, the oceanographic information is of general ecological interest.

METHODS

Temperature and salinity measurements were obtained on 5 transects, named A through E, along the length of the east side of Denman Island from Komas Bluff to Gravelly Bay on Lambert Channel (Fig. 1). On each transect, stations were established and re-occupied on the basis of water depth at high tide: 1, 3, 5, 10, and 15 meters. An Applied Microsystems CTD instrument (Conductivity-Temperature-Depth), lowered by hand, was deployed at each station. Resolution and accuracy (by calibration) of the instrument was as follows: Temperature ± 0.03°C, ±0.01°C, Salinity ±0.07‰, ±0.03‰.

Water samples for dissolved oxygen, pH, total alkalinity, total phosphate, nitrate, and ammonia were also obtained. Depths and locations for water samples on the transects and elsewhere were arranged after consultations with divers conducting visual searches for dead herring. Very few dead fish were found, even after a very active fishery resulting in the removal of approximately 5000 t of herring. To simulate concentrations of dead fish from fallout, about 500 dead herring were dumped and subsequent samples of bottom water were obtained by divers. Water in the vicinity of a sunken and abandoned gillnet containing 500 to 1000 dead herring was also sampled.

RESULTS

Temperature and salinity

Detailed results are presented elsewhere in a data report (Levings 1982). Information from the first 3 inshore stations on each transect (1, 3, 5 m) is focused on in the present report, as this is probably where the majority of herring spawned and eggs hatched.

Over the sampling period, salinity on the more northerly transects was more variable than at locations to the south, well into Lambert Channel (Table 1). On transect A, for example, salinity range was 2.3‰ (26.2 to 28.5‰) compared to 0.5‰ on Transect D (27.3 to 27.8‰), (Table 1). Temperature was less variable, with a slightly narrower range of 1.3°C on Transect C (8.1 to 9.4°C) compared to approximately 1.8°C (8.0 to 9.8°C) at Transect D (Table 1). Variation in density showed patterns parallel to those of salinity (Table 1).

Figure 2 shows a representative vertical profile of properties. The upper 3 m was usually less saline and cooler than deep levels, resulting in a moderate pycnocline between 3 and 5 meters.

Nutrients and dissolved oxygen

In a heavy concentration of spawn on March 7, phosphate and ammonia showed a concentration peak at about 1 m (Fig. 3). Nitrate appeared to be uniformly distributed through the water column (Fig. 3). Ammonia values at 5 m over transect 'spawn', the area of dumped fish, and the abandoned net were compared. In 5 samples, there was very little variation, with a mean value of 0.044 mg L^{-1} and range from 0.036 to 0.055 mg L^{-1}.

Surface levels of phosphate and nitrate were enhanced during the time when 'white water' overlay the spawning ground. Total phosphate values rose after spawning began on March 6, increasing from approximately 0.08 mg L^{-1} on March 4 to about 0.21 mg L^{-1} on March 8 (Fig. 4a). By March 12, total phosphate levels had decreased to 0.10 mg L^{-1}. Nitrate levels showed a similar pattern, peaking at about 0.08 mg L^{-1} (Fig. 4b).

Nutrient and dissolved oxygen data are tabulated elsewhere in a data report (Levings 1982).

Dissolved oxygen values at 3 and 5 m depths, near bottom, were compared at the area of dumped fish and the abandoned net (9 samples) and adjacent transects (11 samples). As judged by a t-test, there was no significant difference ($p<0.05$) between values at the two locations (mean values 8.66 *vs* 7.43 mg L^{-1}, respectively).

DISCUSSION

Salinity and spawning

Although further interpretation of the data are required, it is apparent that herring spawning was more intensive (Haegele, pers. comm.) at the more northerly transects where lower salinities were recorded. The fresher water in these areas may have resulted from the discharge of the Courtenay River, whose estuary is near the north end of Denman Island. On certain transects, especially B and C, fresh water seeps were noted on beaches, and these may have lowered salinities on an extremely local scale. Salinities on the south transects were in the upper end of the range reported by Outram (1975), namely 22.4 to 28.7‰. A correlation between freshwater seeps and herring spawning was also suggested by Rabin (1977) for Humboldt Bay, California. Ginzberg (1968) noted that herring sperm motility persists longer in lower salinity water and thus brackish water spawning may be an advantage for fertilizing eggs.

Nutrients from herring sex products

The nutrient information obtained in this study indicates that the nitrate and phosphate concentrations in surface water was related to milkiness, a phenomenon generally attributed to sperm density (Hourston and Rosenthal 1976). However, available biochemical information suggests that herring eggs might be the source of the phosphate. Inoue et al. (1971) found that Pacific herring eggs yielded a phosphoprotein containing 10.6% phosphorus. At that time this species' eggs contained the most phosphorus of any fish egg reported on. Ginzberg (1968) reported herring sperm are mostly composed of DNA and protamines, which are nitrogenous compounds. The seminal fluid of fish is also high in nitrogen, with a N:P ratio of 4.19 reported for Salmo fontinalis (Ginzberg 1968). The sperm and seminal fluid might, therefore, be a major contributor to the increase in nitrogen observed in this study (Fig. 4). It should also be noted that the values of nitrate reported include the effects of uptake by phytoplankton, and a diatom bloom was occurring in the study area by late March. Whether such blooms can be stimulated by the release of nitrogen from herring eggs and sperm is an intriguing question yet to be answered.

Water quality observations

As noted in the results, there was little evidence of decreases in water quality even when dead fish were artificially aggregated to simulate a "fallout" situation. If large scale effects were occurring, changes in the physical appearance of bottom sediments, decreased dissolved oxygen levels, and increased concentrations of nutrients in bottom waters would have been observed. Conditions might have been expected to resemble those in coastal waters where fish plant wastes are dumped (Dale and Dawson 1975; Champ et al. 1981).

Unlike the sitution reported by Humphreys (1977) where sunstars (Pycnopodia sp.) were observed eating dead herring, there were few predators observed by divers in this study. Carcasses obtained by divers were examined for smaller crustaceans, notably amphipods, which had been attracted to the fish. A few specimens, 1 to 5 amphipods of the family Photidae, were observed on these fish. This was far fewer than expected and less than commonly attracted to herring used for crab bait.

In summary, there was little evidence of degraded water quality or large scale effects such as predator attraction. Gillnet fallout had a minimal effect on the local benthic environment at the Denman Island spawning ground.

ACKNOWLEDGMENTS

Thanks are due to Dr. D. Hay, Pacific Biological Station, for his assistance in the field and administrative help ashore. The majority of the field work and data gathering was conducted efficiently by Mr. T. Ethier of Seakem Oceanography, Sidney, B.C. Thanks are also due to the divers associated with general data collection for their observations on dead herring. The nutrient analyses were performed by Water Quality Laboratory personnel at West Vancouver.

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Table 1. Ranges of salinity (‰), temperature (°C), and density (ρ_t) on four transects at the Denman Island-Lambert Channel herring spawning ground.

	Transect A	Transect B	Transect C	Transect D
Salinity range (‰)	26.2-28.5	27.4-28.9	26.9-28.3	27.3-27.8
Difference	2.3	1.1	1.4	0.5
Temperature range(°C)	8.1-9.4	8.0-9.9	8.3-10.2	8.0-9.8
Difference	1.3	1.9	1.9	1.8
Density range (ρ_t)	20.4-22.0	21.2-22.0	20.8-21.9	21.3-21.6
Difference	1.6	0.8	1.1	0.3
No. of sample dates (Mar. 4 to Apr. 21/81)	5	6	5	5

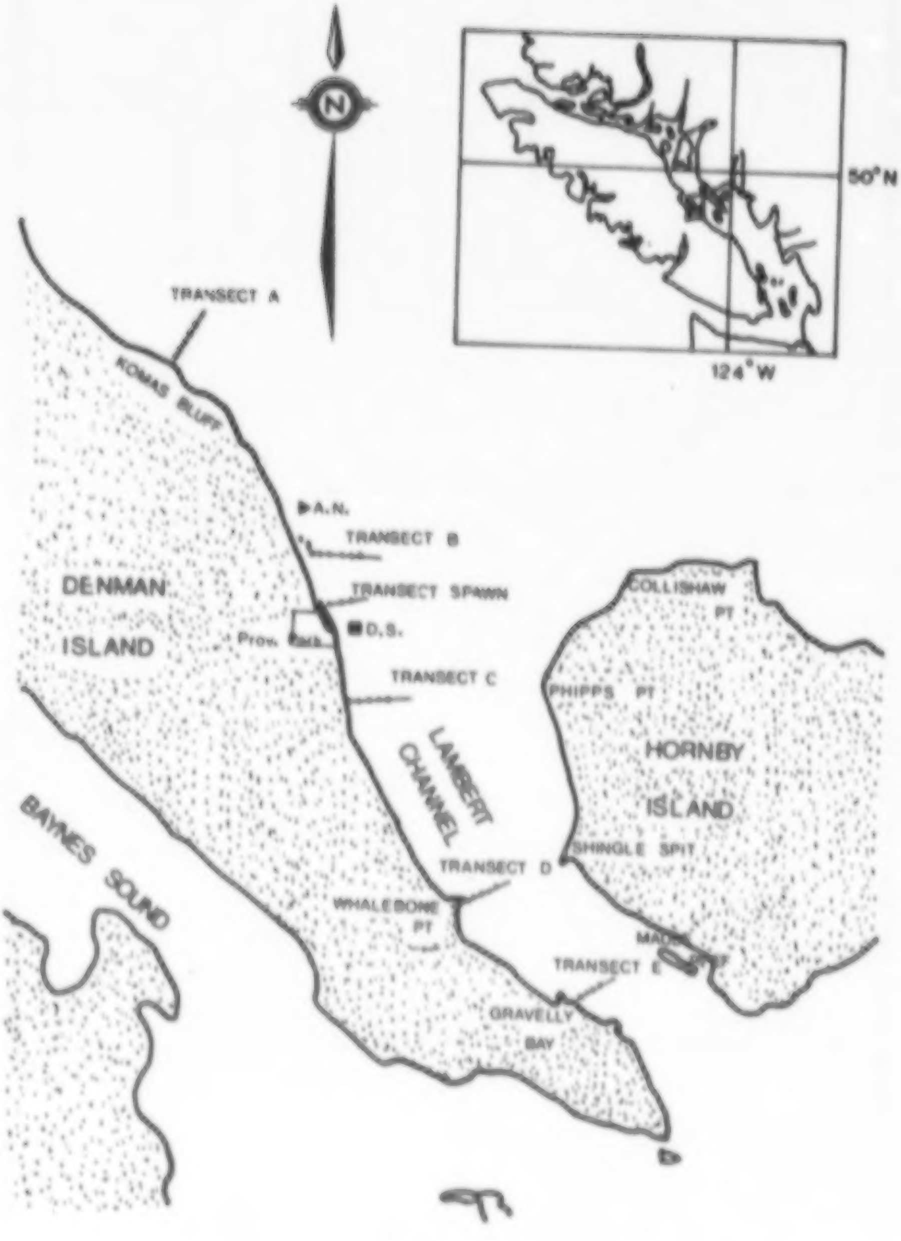

Fig. 1. Chart of the study area and sampling transects on Lambert Channel, east side of Denman. AN indicates abandoned net and DS indicates location of dumped herring.

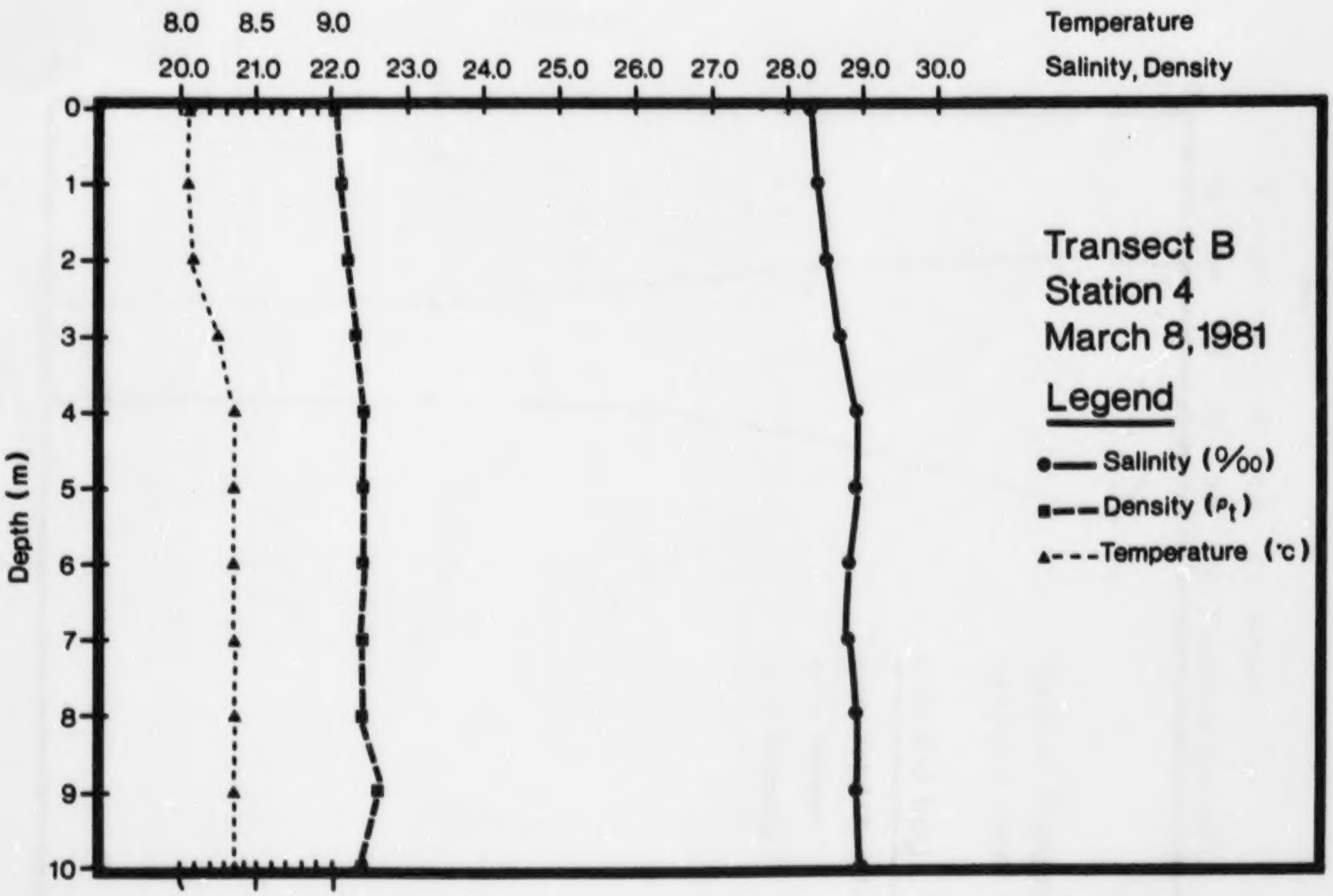

Fig. 2. Representative vertical profile of temperature, salinity, and density, at the study area. (Transect B, Station 4, March 8, 1981, 0945 h).

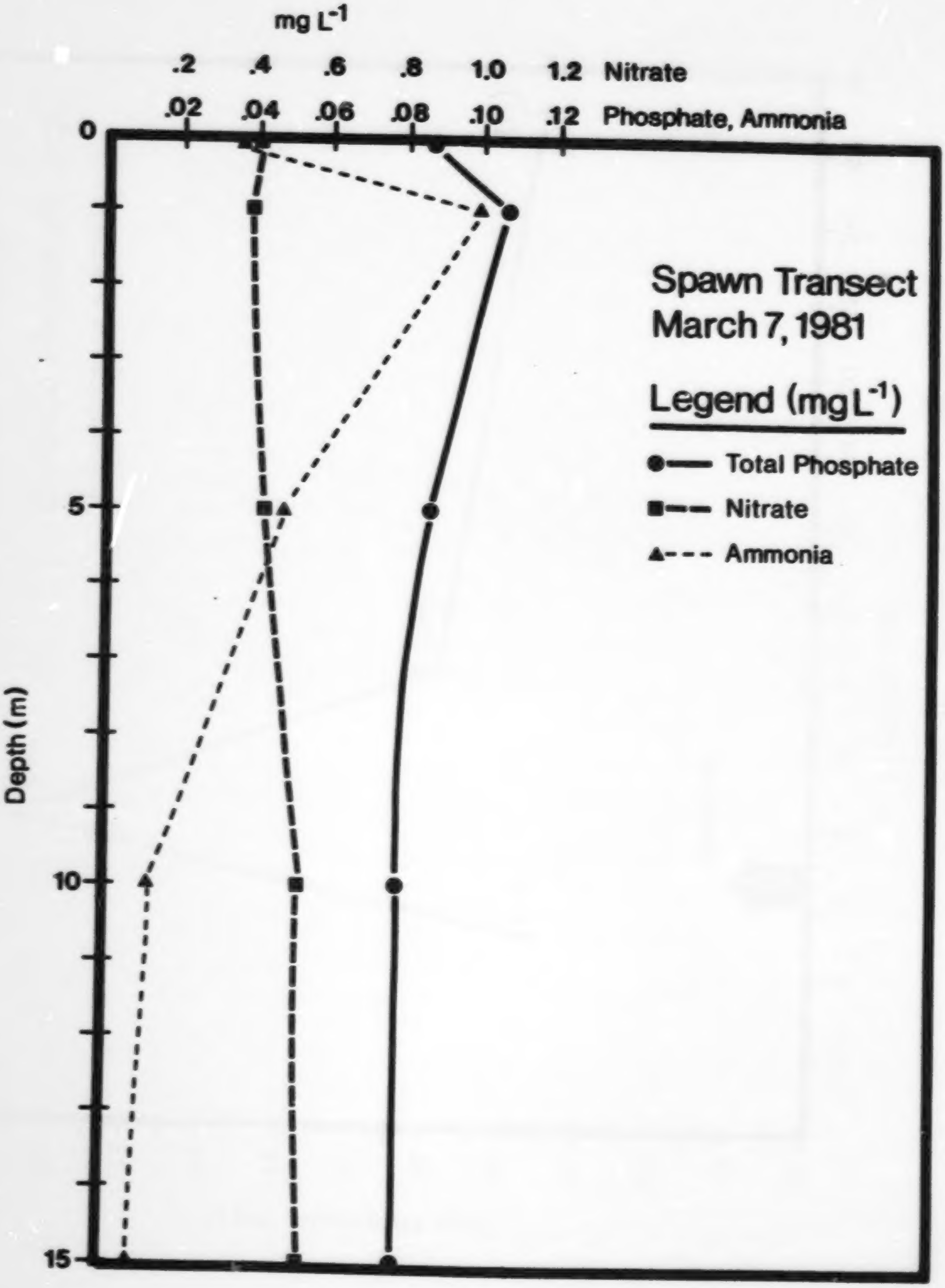

Fig. 3. Vertical distribution of total phosphate, nitrate, and ammonia at Station 5 on transect 'spawn', March 7, 1981, 1000 h.

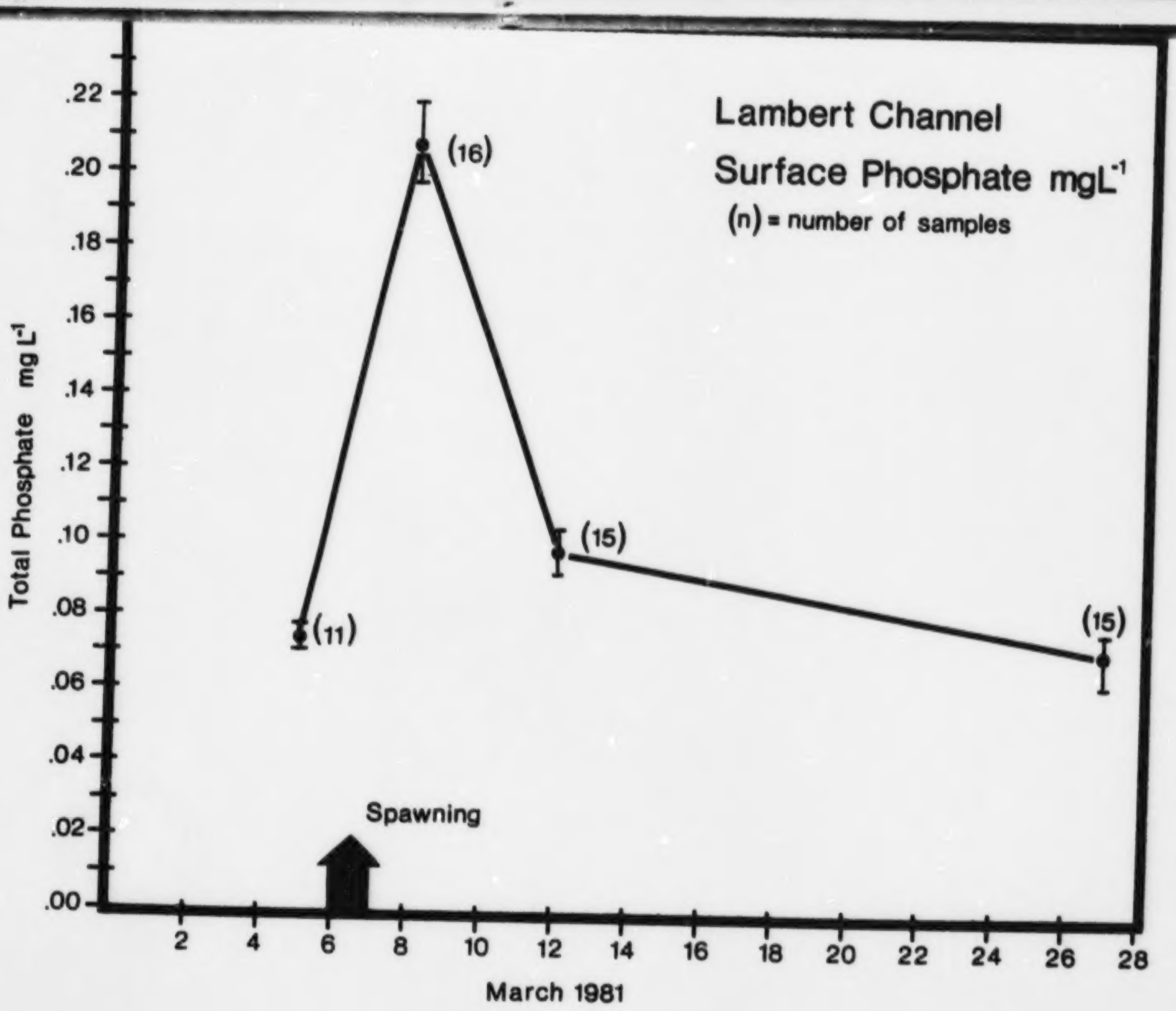

Fig. 4a. Temporal variation in total phosphate at the surface (mg L^{-1}) in Lambert Channel before, during and after herring spawning. Numbers beside data points indicate number of samples used to calculate mean values, which are shown with standard deviations.

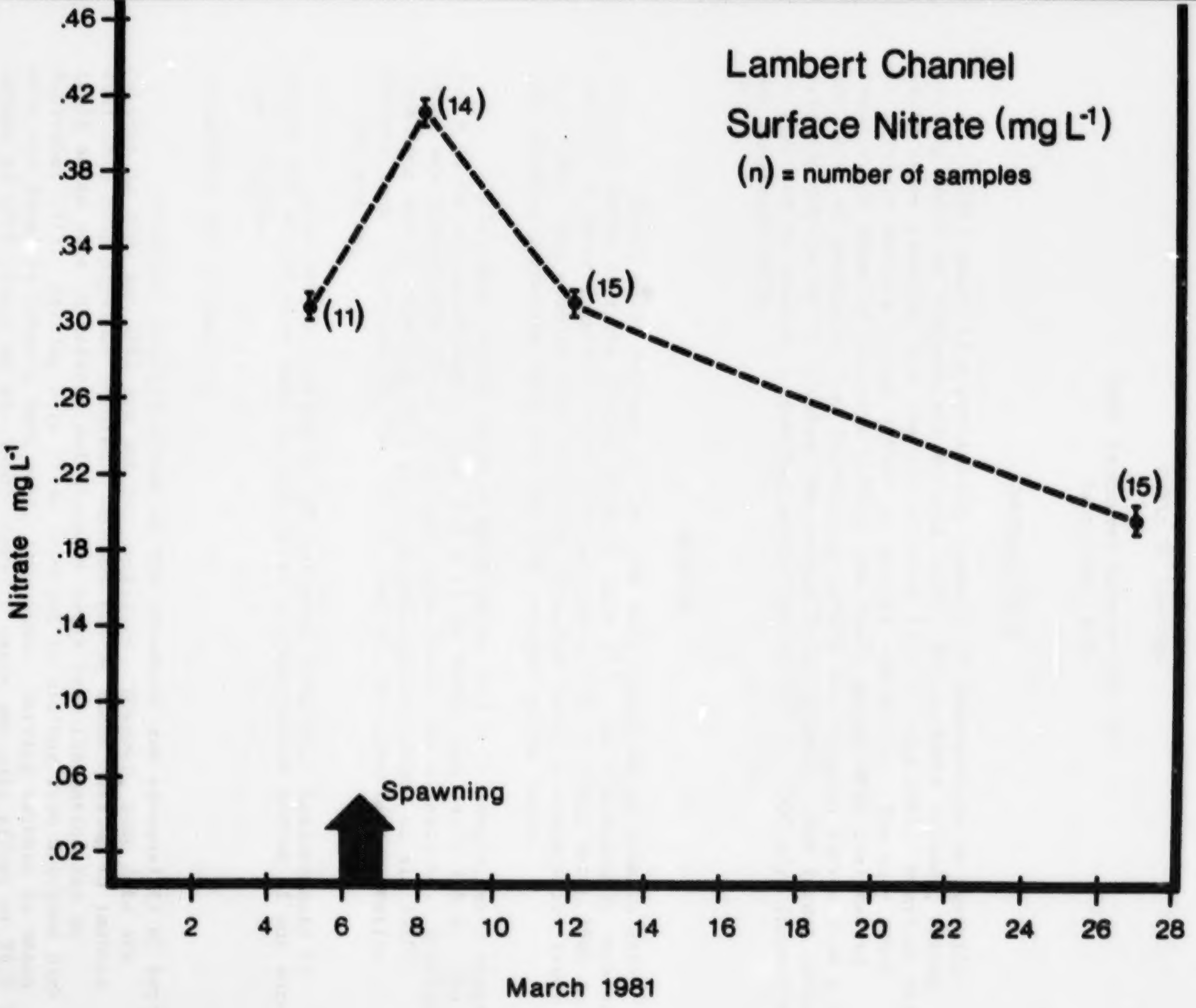

Fig. 4b. Temporal variation in surface nitrate (mg L^{-1}) in Lambert Channel before, during and after, herring spawning. Numbers beside data points indicate number of samples used to calculate mean values, which are shown with standard deviation.

SOME OBSERVATIONS OF JUVENILE HERRING AT THE FRASER RIVER ESTUARY, B.C.

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INTRODUCTION

This paper is a preliminary summary of observations on juvenile herring taken on Sturgeon and Roberts banks, Fraser River estuary, during beach seine sampling over the period March 1979 to July 1981. Previous data on juvenile herring in the Strait of Georgia are scarce. The only other reports are those of Hourston (1957), who dealt mainly with qualitative estimates of abundance, and Barraclough (1967) who reported larvae from a late spawning population at Boundary Bay and/or Point Roberts. The former location is reported to support a spawning population of 2501 to 5000 t/yr (Hourston and Humphreys 1978).

METHODS

Beach seine surveys at low tide were conducted on Roberts and Sturgeon banks over the period March to July 1979, and subsequently regular samples at fewer locations were obtained every 2 to 3 weeks, March 1980 to July 1981. The studies were primarily directed toward a comparative study of how juvenile salmonids used the low tide refuges on the Banks.

Fish were caught using a beach seine 14.7 m in length, with wings 4.0 m (1 cm stretched mesh), bunt 4.9 m (3 mm mesh), and depth 3.5 m. The seine was fitted with about 10 gillnet-type floats and a leadline. Station locations are as reported in a previous publication (Greer et al. 1980): Roberts Bank - Stations 26, 28, 33, 37, and 45; Sturgeon Bank - Station 14, 93, 96, and 156.

Fish were preserved in 10% buffered formalin. Measurements of length and weight were made on fish after a preservation period of not more than 7 months.

Abuandance and seasonality

Detailed interpretations of the abundance and seasonality of herring catches in 1980 and 1981 are not yet available. However, some data are available from previous studies. Goodman (1975) found herring in inshore table seine sets on Roberts and Sturgeon banks over the period May to September 1973. Herring were first reported in mid-May from Sturgeon Bank but were not found on Roberts Bank until late June. Herring catches in beach seines in 1979 (Greer et al. 1980) showed a catch per unit effort of 25.3 from Sturgeon Bank compared to 53.4 on Roberts Bank. These data are from catches made from March to July.

RESULTS

Length frequency data

Sturgeon Bank

Herring taken on Sturgeon Bank in late June and early July 1980 ranged from 25 to 59 mm, with modal peaks at about 30 and 50 mm (Fig. 1). In late July this pattern persisted, with a few larger herring appearing. By mid-August and September, a definite bimodal or multi-modal pattern was evident, with several examples of fish >100 mm. In 1981, juvenile herring with length range 25 to 45 mm were also observed (Fig. 2) but few fish were taken after June.

Roberts Bank

The majority of juvenile herring taken on Roberts Bank were all over 40 mm in length in all samples from both 1980 and 1981. In late June to early July 1980, there was a poorly-defined peak in abundance at approximately 70 mm (Fig. 3). In late July to early August this peak was also present with a few fish in the 35 to 40 mm size. This was the case in early June 1981 also (Fig. 4).

Length-weight relationships

Analyses of length-weight relationships are only partially complete for 1980 data. They should be considered tentative results as the groupings of data used in the results are currently being revised. The length-weight relationships computed for the various locations and dates are as follows:

Location, Date (1980)		Length-Weight Regression Equation[1],[2]
Sturgeon Bank (Stn. 156)	May 7 to July 9	$\log_e wt = -4.203 + (2.903 \cdot \log_e Len)$
" "	July 9 to 30	$\log_e wt = -8.654 + (3.990 \cdot \log_e Len)$
" "	July 30 to Sept 4	$\log_e wt = -7.834 + (3.776 \cdot \log_e Len)$
Sturgeon Bank (Stn. 96)	June 12	$\log_e wt = -5.573 + (3.205 \cdot \log_e Len)$
" "	June 12 to 27	$\log_e wt = -6.440 + (3.426 \cdot \log_e Len)$
" "	June 27 to Aug 12	$\log_e wt = -6.670 + (3.480 \cdot \log_e Len)$
Roberts Bank (Stn. 26, 33,37,45)	June 13 to 20	$\log_e wt = -5.750 + (3.260 \cdot \log_e Len)$
" "	June 28 to July 10	$\log_e wt = -5.031 + (3.029 \cdot \log_e Len)$
" "	July 10	$\log_e wt = -0.1295 + (1.849 \cdot \log_e Len)$
" "	July 10 to July 28	$\log_e wt = -2.566 + (1.189 \cdot \log_e Len)$
" "	July 28 to Sept 24	$\log_e wt = -4.967 + (3.034 \cdot \log_e Len)$

[1] Equations based on sample size of 50 fish.

[2] Weight in mg, length in mm.

Diet studies

Juvenile herring (45 to 55 mm) from Roberts Bank (Stn. 26 of 1979 survey) were examined for stomach contents, and results from 20 fish are given in Table 1. As shown, decapod larvae, harpacticoid copepods, calanoid copepods, gammarid amphipods, and cirriped larvae were among the most common items in the diet. These invertebrates use the eel grass beds as habitats.

DISCUSSION

Because of the dearth of data on juvenile herring elsewhere in the Strait of Georgia, there are few data to compare results with. The only comprehensive data from B.C. waters are from Hourston (1959), who worked in Barkley Sound. Hourston (1959) documented the fact that juvenile herring were strongly oriented toward the shoreline. Using data on herring abundance, temperature, salinity, food supply estimated by zooplankton tows, and the physical appearance of habitats, he concluded that the shelter afforded by the nearshore environment was the most important feature for determining juvenile abundance. However, nearshore-intertidal food resources were not evaluated, and may have been important as the fish probably were not using the "offshore" zooplankton sampled.

In 1979, juvenile herring were about twice as abundant on Roberts Bank compared to Sturgeon Bank, and this difference may be related to salinities and food supply. Although data are not completely interpreted, it is clear that juvenile herring on Roberts Bank are using water with surface salinities >20‰. On Sturgeon Bank, which is much closer to the direct discharge of the Fraser River, salinities were usually <20‰ and frequently ranged down to 0‰ during freshet. Hourston (1959) found that in Barkley Sound average salinities ranged from 17.23 to 29.3‰ where juvenile herring were consistently abundant. Roberts Bank habitats are characterized by eel grass, with ample microcrustaceans available as food. Sturgeon Bank stations were characterized by sand, with available crustacean food being advected from offshore.

The hatching location of juvenile herring found on the Banks is yet to be determined directly. Infrequent and light spawning is reported on Roberts Bank (Fisheries Officers' observations) but not until May, well past the usual period elsewhere in the Straits (March). There must be considerable year to year variation in spawning time in the southern Strait of Georgia, as Cardwell and Koons (1981) reported that the "Point Roberts to mid Birch Bay" (adjacent to Roberts Bank, but in the U.S.) herring spawn from February to June. According to the age-length relationship presented by Hourston (1957) for the Strait of Georgia, the juveniles (modal peak about 70 mm) reported on Roberts Bank in June were about 4 months old and could have come from stocks almost anywhere in the southern Straits. The smaller herring (20 to 40 mm), which were actually more abundant on Sturgeon Bank, would be about 1 to 2 months old and could have come from a late spawning on Roberts Bank, Point Roberts, or Boundary Bay. Barraclough (1967) concluded that the juvenile herring (20 to 25 mm) obtained in July off Sturgeon and Roberts banks in plankton tows were from a late spawning population.

The length-weight relationships obtained in our study were comparable to those presented by Hourston (1957) for herring elsewhere in the Strait of Georgia. The length-weight relationship in 1956 yielded an exponent of 2.76 compared to 3.11 in 1955. These inter-year differences were as marked as the intra-seasonal differences from our data from Roberts Bank, where the coefficient ranged from 1.189 to 3.260. The unusually low coefficients calculated from July 1980 data require further investigations. These low values decreased the mean coefficient from Roberts Bank fish to 2.461 compared to 3.463 on Sturgeon Bank.

ACKNOWLEDGMENTS

Field work to obtain samples were obtained from a collaborative study involving personnel from the Habitat Management and Resource Services Branches of DFO. Thanks are due to G. Sandercock and D. Burt for their efficient laboratory processing of the samples.

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Table 1. Herring gut contents (n = 20).

	Roberts Bank Intercauseway, 11 June 1979	
Item	Percent Number	Percent Frequency
Natantia zoea larvae	37.5	90
Brachyuran zoea larvae	0.1	15
Harpacticoid copepods	32.1	100
Small Calanoid copepods	28.3	75
Scaphocalunus sp.	<0.1	5
Metridia longa	0.1	15
Eurytemora sp.	0.6	35
Acartia sp.	<0.1	5
Anisogammarus pugettensis	0.1	10
Pontogeneia rostrata	<0.1	5
Ischyrocerus anguipes	<0.1	5
Unknown Gammarid	0.5	40
Hyperid amphipod	<0.1	5
Bryozoan larvae	0.3	20
Cirriped cypris and nauplii	0.2	35
Oikopleura	<0.2	10
Tanaidacea	<0.1	5

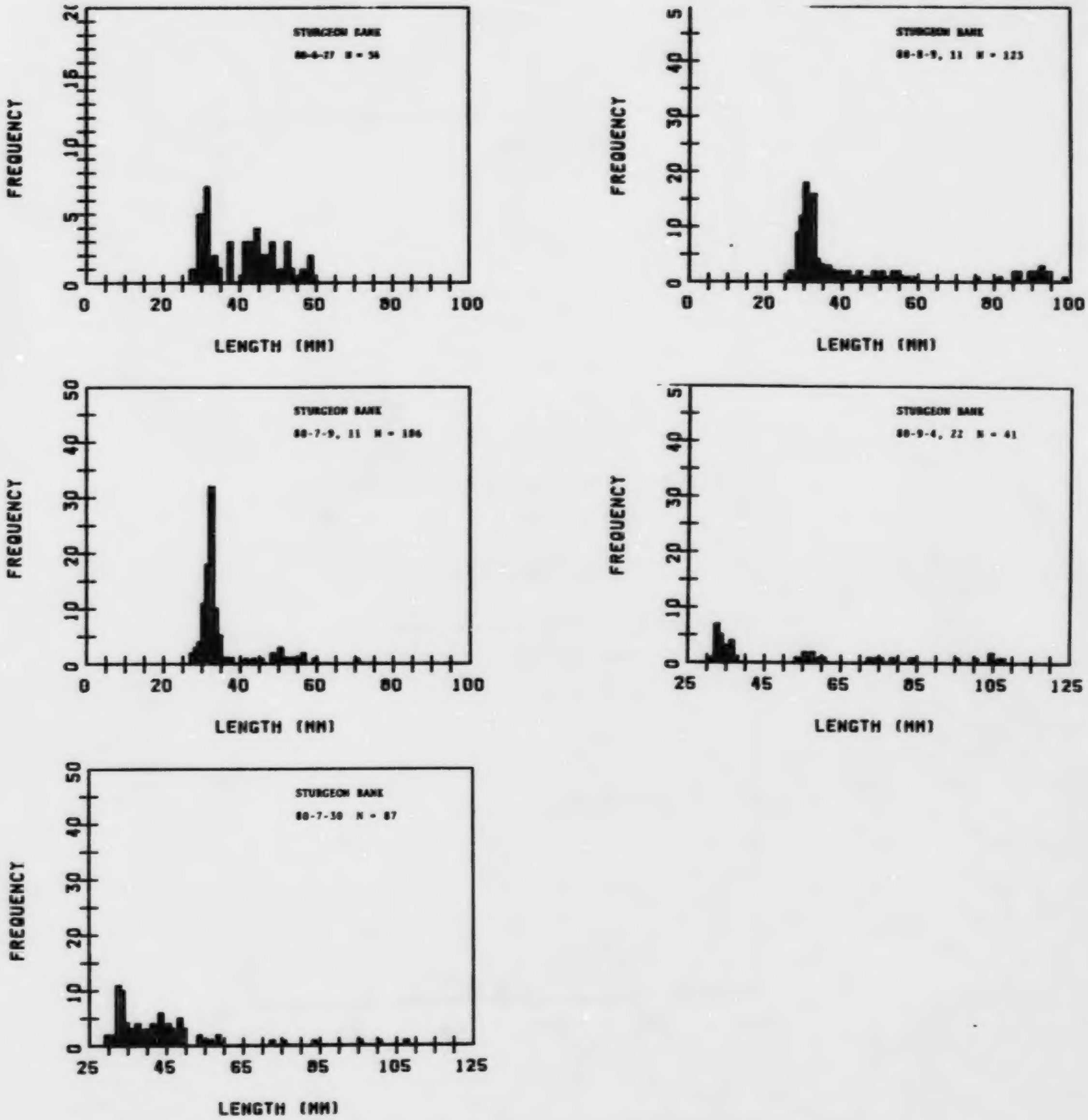

Fig. 1. Length frequency data for juvenile herring taken by beach seine on Sturgeon Bank, Fraser River estuary in 1980.

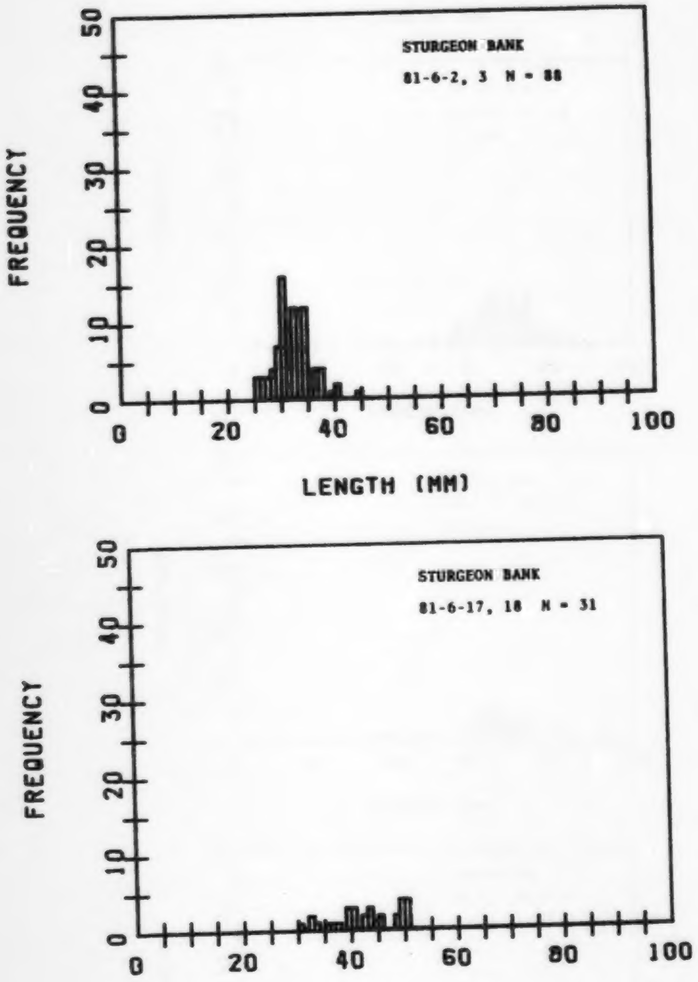

Fig. 2. Length frequency data for juvenile herring taken by beach seine on Sturgeon Bank, Fraser River estuary, in 1981.

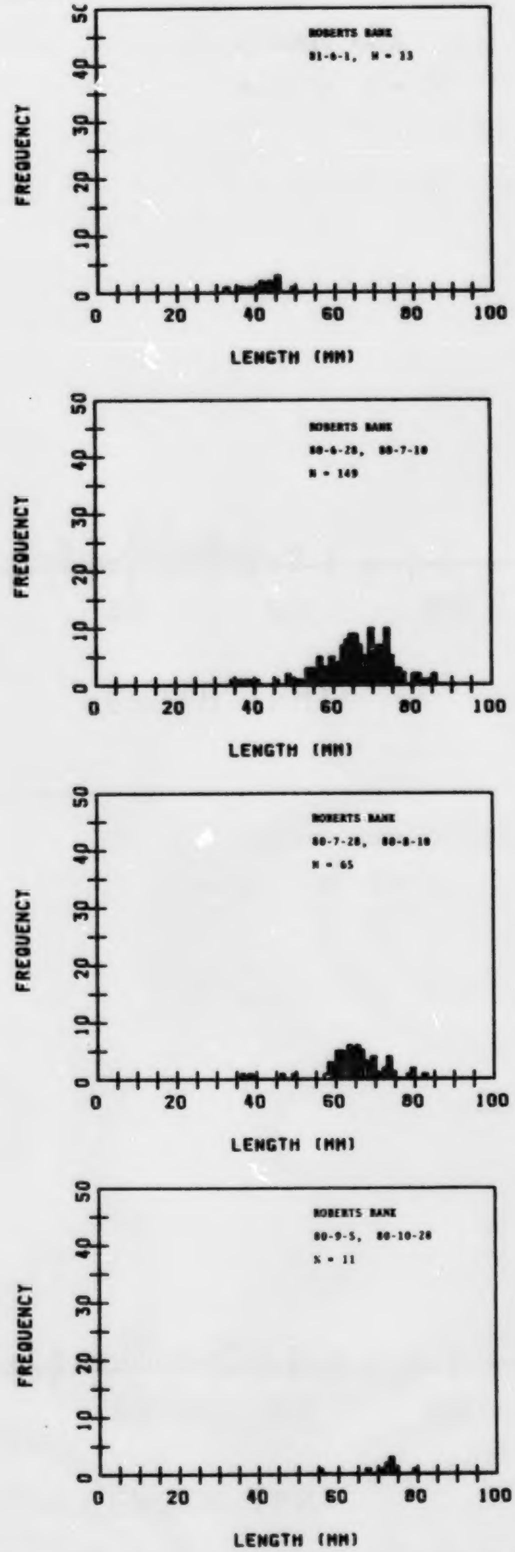

Fig. 3. Length frequency data for juvenile herring taken by beach seine on southern Roberts Bank, Fraser River estuary, in 1980.

Fig. 3. Length frequency data for juvenile herring taken by beach seine on southern Roberts Bank, Fraser River estuary, in [illegible].

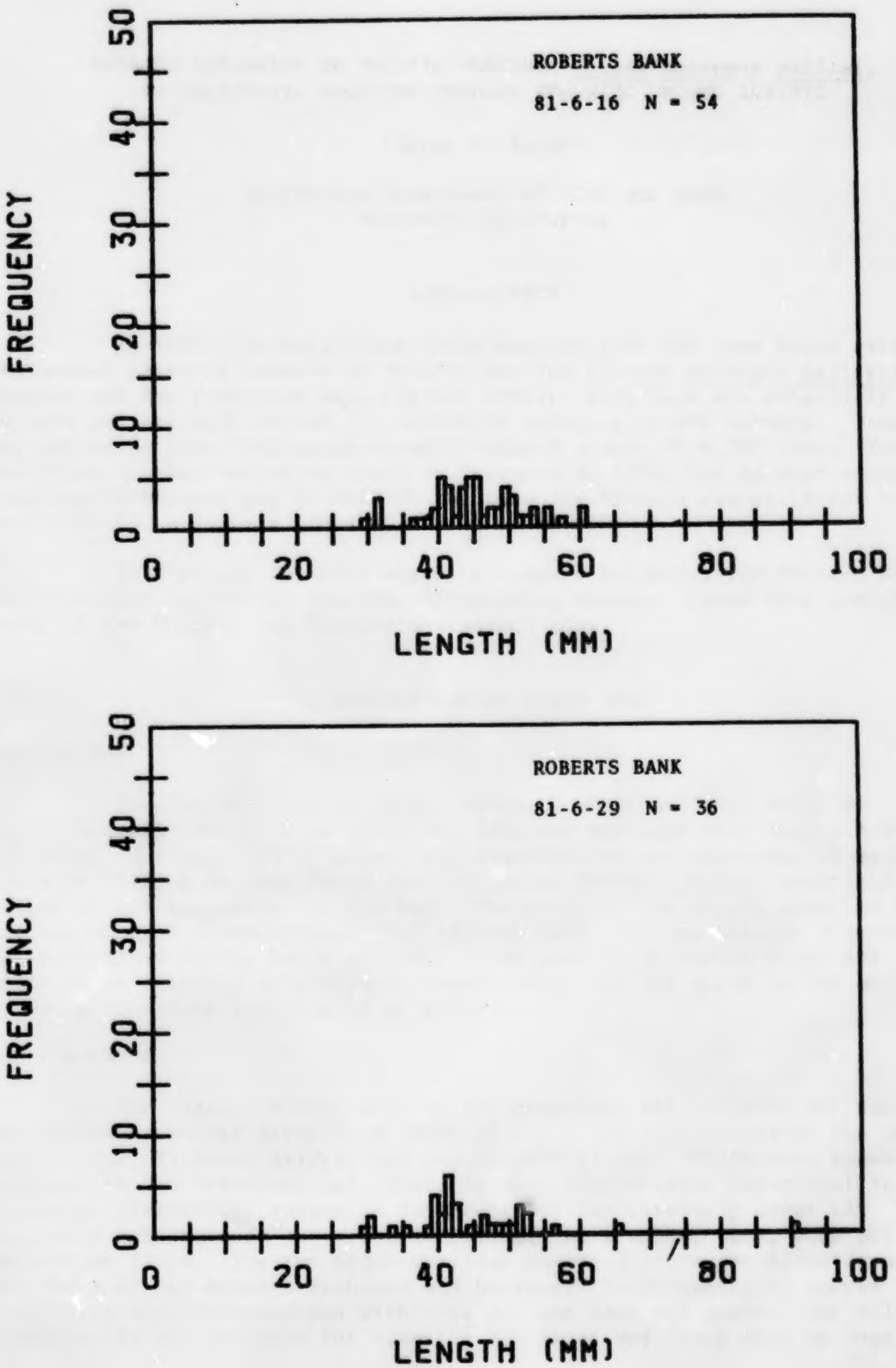

Fig. 4. Length frequency data for juvenile herring taken by beach seine on southern Roberts Bank, Fraser River estuary, in 1981.

BIOMASS ESTIMATES OF PACIFIC HERRING, *Clupea harengus pallasi*, IN CALIFORNIA FROM THE 1980-81 SPAWNING GROUND SURVEYS

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INTRODUCTION

In 1973, the California Department of Fish and Game began estimating the annual spawning biomass of Pacific herring (*Clupea harengus pallasi*) in Tomales and San Francisco bays (Spratt 1981). Both bays are relatively small in area and are well suited for intensive spawning ground surveys. Tomales Bay estimates have fluctuated normally around a mean of 6,000 tons. The San Francisco Bay estimates began to increase in 1978, due to improvements in sampling techniques and in 1979-80 the spawning biomass was estimated to be nearly 53,000 t (Spratt 1981).

This report includes spawning biomass estimates for Tomales Bay and San Francisco Bay during the 1980-81 spawning season. These data are the basis of the herring roe fishery management plan.

DESCRIPTION OF STUDY AREA

Tomales Bay

Tomales Bay lies in Marin County, a short distance north of San Francisco. It is 20 km (12.5 mi) long and averages more than 1.5 km (0.9 mi) wide. Hardwick (1973) mapped the distribution and abundance of marine flora in Tomales Bay and found that eel grass *Zostera marina*, comprised 75% by weight of all vegetation in the bay. The distribution of eel grass in Tomales Bay has changed slightly each year (Spratt 1981) and the present distribution was determined during March of 1981. Other species of marine flora are utilized as spawning substrate in Tomales Bay, but eel grass is the only spawning substrate included in my surveys.

San Francisco

The regular survey area in San Francisco Bay includes all shoreline and shallow subtidal areas to a depth of 4.6 m (15 ft) bounded by the Golden Gate Bridge, Richmond Bridge, and the Oakland Bridge. While most spawns are subtidal in San Francisco Bay, there is also considerable intertidal spawning activity. Intertidal spawns in San Francisco Bay literally cover all available substrate in the area, including: bare rocks, sand, pier pilings, and marine flora. The two major subtidal spawning areas are Richardson Bay and the east bay between Richmond and Oakland. They consist of sparse beds of *Gracilaria* spp. interspersed with *Ulva* sp. and some eel grass. The only areas consistently not utilized for spawning are broad mud flats with no vegetation.

METHODS

Tomales Bay sampling techniques

This season, spawning ground surveys were conducted from December 1, 1980 to March 20, 1981. Spawn sampling techniques have remained relatively unchanged since 1973 (Spratt 1981). Every eel grass bed was sampled daily from a 4.6 m (15 ft) boat by towing a vegetation sampler through the bed.

The distribution of eel grass changes yearly, new beds are discovered, old ones disappear, and the area of some beds change significantly.

Every year in March after spawning has nearly stopped, the area of all eel grass beds is remeasured and this new data is used to calculate all of the season's spawns. Previous estimates of eel grass density ranging from 0.5-4.0 kg/m^2 (Spratt 1981) were applied this season to each bed by subjective on site inspections.

San Francisco Bay sampling techniques

Techniques used in San Francisco Bay to estimate spawning biomass have evolved over the years. Before 1978, sampling biomass estimates for San Francisco Bay were determined by sampling intertidal (shoreline) spawns only. In January of 1979, a major subtidal spawn was located in Richardson Bay, and the following season, seven subtidal spawns were located which accounted for 79% of the season's spawning activity (Spratt 1981). In order to compute biomass from subtidal spawns, it is necessary to determine the weight (kg/m^2) of vegetation present in the spawning area. In the fall of 1979, Department divers collected quantitative samples of vegetation from Richardson Bay. This vegetation survey was expanded in the fall of 1980 to include Belvedere Cove, Tiburon, Kiel Cove, and the east bay between Richmond and Oakland. The boundaries of known vegetation beds were determined by dragging a vegetation sampler through them. Sampling stations were selected randomly by placing a grid over the beds, and numbering points where grid lines intersected. In the east bay 15 stations were selected and in the Richardson Bay area 20 stations were selected. Divers removed all vegetation from three 1/4 m^2 quadrats at each station. The vegetation was damp dried and weighed to the nearest gram immediately after collection. When a subtidal spawn occurs, the vegetation sampler is used to collect samples and determine spawning area (m^2). The number of eggs/kg of vegetation are determined using techniques developed in the 1979-80 season (Spratt 1981). The estimate of egg deposition is the product of number of eggs/kg vegetation, kg vegetation/m^2, and spawn area (m^2).

Biomass Computation

The techniques used to estimate total number of eggs deposited during a season differs between Tomales and San Francisco bays. However, conversion from numbers of eggs spawned to tons of adults is identical for both bays.

Hardwick's (1973) estimate of fecundity was used to convert numbers of eggs to tons of herring. Hardwick estimated fecundity at 114 eggs/gram of herring (both sexes combined) for Tomales Bay herring, and that 103.5 million eggs would be produced by one ton of adult herring.

The total eggs deposited during the season is the sum of the estimates of each individual spawn. The number of eggs spawned is converted to short tons of spawners by the conversion factor of $.996 \times 10^{-8}$, which is the reciprocal of fecundity.

RESULTS

Tomales Bay

Two more eel grass beds were discovered this season; bed 1A near the south end of the bay, and bed 20A which is west of Tom's Point. These two beds were found when large numbers of gulls were observed circling in the area as herring were spawning.

These beds may not be newly formed but I believe this is the first time they were utilized for spawning since our survey began. There is now a total of 31 known eel grass beds in Tomales Bay. Bed measurements in March 1981 revealed that the total amount of eel grass available for spawning is over 4 million m^2.

The first spawn located this season occurred on December 15, 1980 and a total of 6 spawning runs occurred utilizing 24 individual spawning sites. The last two spawns of the season on February 2 and February 17, 1981 were much larger than estimates indicated. Part of the February 2nd spawn was on eel grass at bed 1A, but the major part of the spawn utilized a Gracilaria sp. bed near Sacramento Landing. On February 17, 1981 herring spawned on an extensive bed of Gracilaria sp. near Marshall. Both of these spawn are not included in my estimates because no density (kg/m^2) estimates of Gracilaria were available.

I estimate a minimum spawning escapement of 5,135 t. The commercial herring roe fishery takes herring just prior to spawning, therefore, the spawning biomass estimate for the season should include the catch. The catch of pre-spawners increases the biomass estimate for the 1980-81 season to 5,583 t of herring. This should be considered a minimum estimate because two significant spawns are not included.

San Francisco Bay

Significant subtidal spawning in San Francisco Bay was first discovered during the 1978-79 season, and in the following season (1979-80), 79% of the spawning biomass estimate was derived from subtidal spawning (Spratt 1981). Subtidal spawns are now considered to be more important than intertidal (shoreline) spawns.

The known subtidal spawning areas of the bay were surveyed by Department divers in November 1980 to estimate the density of vegetation. Vegetation densities were highest in Richardson Bay (.083 kg/m^2) and Kiel Cove (.908 kg/m^2). The vegetation survey of the east bay revealed a mean density of .002 kg/m^2 except at one station near Berkeley which had a density of .629 kg/m^2.

The first spawn of the season was located on November 17, 1980 near Tiburon. There were at least 10 spawning runs during the season and spawn was deposited at 6 locations in the bay. Subtidal spawns were less than the 1979-80 season, but still accounted for 56 percent of the estimate.

Richardson Bay, Kiel Cove, and associated shoreline accounted for 90% of the season's spawning activity. The east bay was apparently less suitable to herring because of the low vegetation densities.

I estimated spawning escapement at 59,615 t of herring. The commercial herring roe fishery catch of pre-spawners was 5,826 tons. Including the catch, the spawning biomass for the 1980-81 season is 65,441 t, the highest estimate to date.

DISCUSSION

Tomales Bay

Spawning ground surveys in Tomales Bay are begun on December 1st each season. It is possible that some spawning occurs in November, as was demonstrated in San Francisco Bay the past two seasons. However, surveys are conducted to encompass the time of peak spawning activity in the bay, which is January and February. Since 1973, January and February have combined for 86% of all spawning activity (Table 1). Within this time frame, there has been a shift in the time of peak spawning. In the past three years, 91% of the spawning has occurred in January.

This shift to earlier spawning began in the 1976-77 season and now appears to be stabilized in January. The cause of this change is not completely understood, but could be related to rainfall. California has been in the midst of a drought of varying degrees that began in 1976.

The Tomales Bay biomass estimate has ranged between 4,728 t in 1975 and 22,163 t in 1978. Excluding the anomalous 1978 season, the Tomales Bay estimate has averaged nearly 6,000 t/yr (Table 2). The spawning population in the bay currently appears stable and fluctuates normally from year to year.

San Francisco Bay

The months of peak spawning activity in San Francisco Bay are December, January, and February (Table 3). However, in the past four seasons there has been a shift in spawning activity to December and January, with over 90% of spawning activity completed by the end of January. This same phenomenon occurred in Tomales Bay over the past four seasons.

The estimate of herring spawning biomass in San Francisco Bay has more than doubled since the 1976-77 season (Table 4). There is little reason to believe that the population has actually increased. The estimate of spawning biomass has increased due to the following changes in methodology:

i. extensive subtidal spawning areas were included in surveys beginning with the 1979-80 season,
ii. the month of November was included in surveys beginning with the 1980-81 season.

The estimated herring spawning biomass in San Francisco Bay for the 1980-81 season is 65,441 t, the best estimate obtained to date. Fine tuning of methodology, particularly the vegetation surveys, will improve our estimates again next season, but this is not expected to result in a significant increase in the population estimate. Assuming that all the major spawning areas in the bay have been discovered, the population can be expected to fluctuate normally in the future, as the Tomales Bay population does. Herring are noted for natural cycles in abundance, and decreases in population size in the future can be expected to occur.

ACKNOWLEDGMENTS

I wish to thank Walter Earl, John Finley, Mary Gillman, and William Hardy who braved the elements to collect samples of herring eggs. Department divers James E. Hardwick and Frank Henry collected subtidal vegetation samples in San Francisco Bay.

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Table 1. Tomales Bay monthly herring spawning biomass expressed as a percent of season total.

Season	Month			
	Dec	Jan	Feb	Mar
1973-74	9	36	55	-
1974-75	10	65	22	3
1975-76	6	68	25	1
1976-77	42	49	5	4
1977-78	5	93	2	-
1978-79	No survey was conducted.			
1979-80	12	86	2	-
1980-81	4	95	1	-
Monthly average	13	70	16	1

Table 2. Tomales Bay herring spawning biomass estimates, 1973-74 through 1980-81 seasons.

Season	Spawn estimate (tons)	Catch (tons)	Spawning biomass (tons)
1973-74	6,041	521	6,562
1974-75	4,210	518	4,728
1975-76	7,769	144	7,913
1976-77	4,739	344	5,083
1977-78	21,517	646	22,163
1978-79	-	448	-
1979-80	5,420	603	6,023
1980-81	5,135	448	5,583

Table 3. San Francisco Bay monthly herring spawning biomass expressed as a percent of seasonal total.

	Month				
Season	Nov*	Dec	Jan	Feb	Mar
1973-74	-	8	-	45	47
1974-75	-	1	66	33	-
1975-76	-	12	62	21	5
1976-77	-	18	33	49	-
1977-78	-	52	44	4	-
1978-79	-	14	76	10	-
1979-80	5	72	14	9	-
1980-81	5	36	48	10	1
Monthly Average	1	27	43	23	6

*November was not surveyed prior to the 1979-80 season.

Table 4. San Francisco Bay herring spawning biomass estimates, 1973-74 through 1980-81 seasons.

Season	Spawn estimate (tons)	Catch (tons)	Spawning biomass (tons)
1973-74	4,241	1,938	6,179
1974-75	26,820	514	27,334
1975-76	25,318	1,719	27,037
1976-77	22,375	4,201	26,576
1977-78	3,682	4,987	8,669
1978-79	32,580	4,121	36,701
1979-80	46,439	6,430	52,869
1980-81	59,615	5,826	65,441

SESSION V:

HABITAT PROTECTION - A DISCUSSION

HABITAT PROTECTION

Bob Trumble

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Seattle, Washington

BRIEF OUTLINE OF HERRING PROTECTION POLICIES

I. Alaska
   A. Corps of Engineers permit application review - case by case.
   B. No written herring-specific policies.

II. British Columbia
   A. Ministry of Transportation permit application review - case by case.
   B. Federal Fisheries Act - adequate language for habitat protection, difficult to enforce legally, but still an effective tool.
   C. No written herring-specific policies, both Federal and Provincial regulations are more general.
   D. Would object to any major action disrupting spawning grounds.

III. Washington
   A. Corps of Engineers permit application review, case by case.
   B. Department of Fisheries Hydraulic Permit which a developer must obtain before construction.
   C. Written herring specific criteria developed by Department of Fisheries and used by other resource agencies during permit review:
      1. No permanent destruction of herring spawning habitat between +3 ft to -15 ft measured from mean lower low water mark.
      2. Certain timing restrictions.
      3. Mitigation is not an acceptable alternative.
      4. Some non-permanent spawning ground disruption is permitted (i.e., mechanical clam digging).

IV. Oregon
   A. Corps of Engineers permit application - case by case.
   B. Certain general state coastal zone goals guiding development.
   C. No known written herring-specific policies.

V. California
   A. Corps of Engineers permit application review, case by case.
   B. No written herring-specific policies.
   C. Internal Review
      1. Oppose any destruction of known herring spawning grounds.
      2. Mitigation a doubtful alternative.

DISCUSSION

Spawning grounds are generally geographically definable, and are obviously important to a spawning stock. All agencies supported efforts to minimize the destruction or disruption of them, especially during spawning season. There is no clear instance of a stock successfully moving its spawning area as a result of destruction or major alteration of their original spawning area. It is unknown if the stock simply dies out or is assimilated into other spawning stocks. Rigorous protection of spawning beaches may shift development into other, perhaps adjacent areas; the effect on eggs, or larvae, is unknown. It also isn't known whether the egg stage, or the pre-metamorphosis larval stage (less than 20 mm) is the more important in determining year-class strength. These larvae are very shoreline oriented, distributed by the tide, and tend to associate with areas of high primary productivity and high molluscan production, at least in parts of B.C. Some day it may be possible to define areas of high primary productivity near major spawning beaches and assess their importance to larval production. If critical larval rearing areas are discovered, perhaps certain protection can be extended to them on activities deleteriously affecting water quality. At this time, however, only major spawning grounds and spawn timing are generally known; consequently, habitat protection must be limited to these until more is known of larval requirements.

SESSION VI:

OTHER STUDIES

ROLE OF LARVAL SURVIVAL IN DETERMINATION OF YEAR-CLASS STRENGTH OF PACIFIC HERRING

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ABSTRACT

The relative abundance of newly hatched larvae of Pacific herring taken in field collections declines sharply within the first month after hatching. The initiation, duration, and magnitude of this decline corresponds closely with the time required for irreversible starvation in the laboratory. Dry weights of larvae from field samples were frequently less than those of laboratory reared larvae subjected to prolonged and irreversible starvation. These observations are consistent with the hypothesis that starvation may significantly affect larval survival. However, the role of larval survival in determination of year-class strength is not clear. There is substantial geographic variation in location and timing of spawnings and it follows that if conditions affecting larval survival varied geographically, and if larval survival determines year-class strength, then year-class strength should vary geographically. This does not seem to be the case. Strong year-classes are found over wide geographic areas and among different stocks that have different spawning (and larval survival) times. The implication is that factors other than larval survival may be important in determination of year-class strength.

SOME ASPECTS OF THE TROPHIC ECOLOGY OF PACIFIC HERRING IN PUGET SOUND

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INTRODUCTION

The "Salmon-Herring Predator/Competitor Interactions Project" was initiated by the Washington Department of Fisheries to comprehensively examine the trophic ecology of salmon, herring, and their potential predators and competitors in Puget Sound. In this paper, I summarize aspects of the trophic ecology of herring that are based upon the portion of this project conducted between August 1978 and September 1979. Specifically, the food habits of herring, competitive interactions among herring and salmon, and predation on herring will be addressed. As there is considerable data yet to analyze (collected between October 1979 and March 1981), conclusions presented here are still preliminary.

APPROACH

Studies were conducted in Puget Sound south of Possession Pt. The sampling program was designed to determine whether differences in food habits were associated with predator size, habitat, time of day and year, and area of Puget Sound. Beach seines were used to collect fish from shallow, sublittoral habitats (mostly juvenile fish), townets from nearshore, pelagic habitats (mostly juveniles), and purse seines and hook-and-line from more offshore pelagic habitats (mostly adults). Pelagic zooplankton populations were sampled concurrent with beach seining using a push net procedure (Cardwell et al. 1978). Stomach and zooplankton samples were processed by the University of Washington's Fisheries Research Institute.

RESULTS

Food habits of herring

To date, 553 herring stomachs have been analyzed. Herring tend to eat a relatively large number of individual organisms, as the mean number of organisms per stomach, depending on gear type and size of herring, was 106 to 208. Results of diel sampling studies suggest that herring are primarily diurnal and most probably crepuscular foragers.

The diet of all sizes (38 to 215 mm standard length) of herring was largely pelagic invertebrates (Table 1). Juvenile herring (collected from shallow sublittoral and nearshore pelagic habitats) primarily ate calanoid copepods, decapod crab larvae, and euphausiids whereas adult herring (collected from offshore pelagic habitats) largely ate euphausiids and decapod crab larvae. Herring diets changed as a function of fish size, time of year, and habitat, all of which influence to some degree what prey is available to the herring. In general, the size of prey eaten by herring increased with increasing fish size.

Competitive interactions

One objective of these studies was to examine the degree of competition among salmon and herring for similar food items. Competition was defined as essentially the demand by two or more individuals of the same or different species for a common resource that is actually or potentially limiting. At this point, my analysis of competition has been limited to examining diet similarity between herring and salmon using overlap measures; in these analyses, comparisons of diet similarity were made with as much specificity (e.g., predator size and location) as possible. It was assumed that the greater the dietary overlap the higher the likelihood of competition. Analysis of diet overlaps suggested that in shallow, sublittoral habitats, herring may compete with juvenile and subadult coho salmon. No other overlap values were high enough to suggest competition.

If herring and salmon do at times compete for similar prey, then there exists the possibility that herring can outcompete salmon for these common prey. Under the right circumstances, herring may cause salmon to switch to alternate possibly less suitable prey which may adversely affect the growth and survival of salmon. Thus, herring may at times be more of a detriment to salmon populations than a benefit (i.e, as a prey item of salmon).

Predation on herring

Results of this project and other data sources (much of it unpublished) were used to examine predation on herring by Puget Sound fishes. Fifteen species out of 147 (10.2%) that occur in Puget Sound eat herring (Table 2); of these species, chinook salmon, dogfish, hake, and walleye pollock would seem to be the major herring predators. In addition, a number of species of birds and mammals also consume herring.

The best data I have available for looking at some specifics of herring predation is for subadult and adult chinook salmon in Puget Sound (obtained from hook-and-line and purse seine samples). Herring were a major diet item of chinook in all months analyzed (August 1978 to September 1979), occurring in 31% of the 349 chinook stomachs analyzed with food. Overall, 61% of the prey biomass consumed by the chinook was herring. Herring were most important in diets in winter and spring and least important in summer and fall, and when herring occurred in stomachs, there was an average of 2.2/stomach. The mean standard length of 120 whole herring measured from chinook stomachs was 110 mm (standard deviation = 35 mm), and most (73%) were between 75 and 135 mm or less than 2 yr old.

Clearly, herring are a major prey item of resident chinook salmon, in addition to several other fish (particularly economically important ones) in Puget Sound. However, the significance of herring as a forage item to Puget Sound fish, especially resident salmon stocks, has been and still is an important and controversial issue. The question is often asked: are herring a "required" food item of Puget Sound salmon? The issue has taken on added importance in recent years due to increases in the release of artificially propagated salmon, concomitant increases in herring fisheries, increases in angler pressure, and periodic shortages of "bait-sized" herring. While information collected by this and several other studies provide clues to this issue, no definitive conclusions are yet possible, primarily because these studies were not conducted to specially address the problem. Examination of available information does not suggest that herring are a required food item per se, i.e., salmon do not require herring to live. Instead, salmon seem to be quite opportunistic; for example, in Puget Sound, salmon stomachs can be full of prey other than herring, such as crab larvae or euphausiids (Fresh et al. 1981). Moreover, stomach analysis of salmon in areas other than Puget Sound (e.g., Pacific Ocean, British Columbia) also show that salmon often eat prey other than herring (e.g, anchovy, pilchards, euphausiids) (Healey 1976; Prakash 1962). Herring seem to contribute to a food rich environment in Puget Sound that supports resident salmon populations. Ultimately, we must consider whether significant declines in herring stocks, due to such factors as destruction of spawning habitat and juvenile rearing areas would cause salmon populations to migrate from the area or would there be enough alternate prey available (e.g., sandlance or euphausiids) to provide sufficient food for the salmon.

SUMMARY

As a summary of the trophic ecology of herring, I would like to present a simplified representation of the portion of the total Puget Sound food web (partially adapted from Simestad et al. 1979) involving herring (Fig. 1). This figure serves to illustrate the importance of herring. The basis of this food web is autotrophic (i.e., phytoplankton) production which is grazed by herbivorous pelagic zooplankton (e.g., calanoid copepods). Herbivorous zooplankton are in turn consumed by larger zooplankton in addition to some fish (i.e., secondary consumers). Secondary consumers are in turn eaten by tertiary consumers such as salmon, birds, and mammals. Herring primarily occupy the important role of secondary consumer and thus transfer energy from lower trophic levels (phytoplankton and primary consumers) to upper trophic levels occupied by many economically important fish such as salmon.

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Table 1. Major prey items (in terms of % biomass) of Pacific herring by habitat in Puget Sound, August 1978 to September 1979.

	% biomass of prey by habitat		
	Shallow Sublittoral	Nearshore Pelagic	Offshore Pelagic
Food items			
Calanoids	42	64	5
Brachyura larvae	23	2	8
Euphausiids	8	26	85
Harpacticoids	3	2	
Cyclopoids	3	1	
Amphipods	8	1	1
Chaetognaths	10		
Predator Characteristics			
No. of stomachs examined	204	155	194
No. empty	30	63	31
Mean standard length (mm)	96	82	141

Table 2. Species of Puget Sound fish that eat herring and the relative importance in diets (P = Primary: >50% biomass in the diets; S = Secondary: 10-50% biomass; I = Insignificant: <10% biomass; ? = undefinable).

Species	Importance
Spiny dogfish	P
Northern anchovy	I
Chinook salmon	P
Coho salmon	S
Pink salmon	I
Steelhead trout	S
Cutthroat trout	I
Pacific cod	S
Pacific hake	P
Walleye pollock	P
Black rockfish	?
Lingcod	?
Buffalo sculpin	I
Staghorn sculpin	S
Sand sole	I

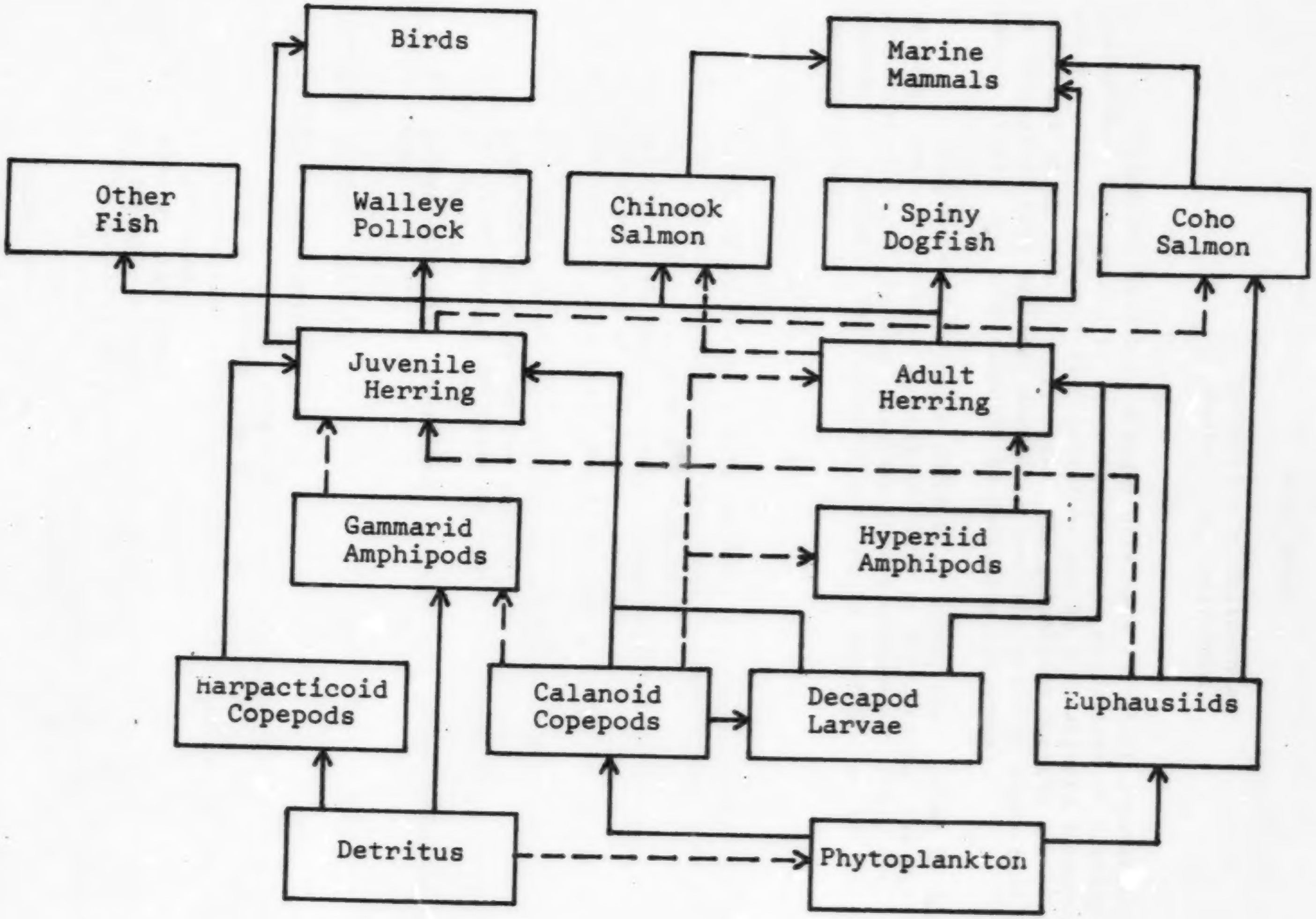

Figure 1. Representation of the segment of the Puget Sound food web involving herring (partially adapted from Simenstad et al., 1979). Solid lines designate primary linkages and dashed lines designate secondary linkages.

[illegible]

PARASITES AS BIOLOGICAL TAGS FOR HERRING

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Parasites have been successfully used for stock separation, in recruitment studies and to trace the seasonal migrations of herring. If the proper criteria are satisfied parasites can be a relatively inexpensive indicator of the hosts' activities. The guidelines for the use of parasites as biological tags has been developed over the years by Sindermann (1957), Kabata (1963), and most recently by MacKenzie (in press).

MacKenzie, in a paper which will appear next spring in Applied Biology, presents several general rules to be followed for the use of parasites as tags. He also suggests the requirements for specific types of population studies. The following outline is adapted from the above recommendations.

General Rules:

1. Levels of infection should not vary significantly in the study area.
2. Environmental conditions throughout the study area must be in the physiological range of the parasite.
3. Ectoparasites should remain firmly attached to the host or at least leave evidence of its recent presence.
4. Preferably, a parasite should be easily detected in the host and identified.
5. The life span of the parasite or evidence of its past presence should cover the duration of the study.
6. Parasites should not cause selective mortalities or behavior changes in the host.
7. Unless otherwise determined, compare only hosts of the same age and sex.

Specific types of studies:

1. Stock separation
   a. Parasites with single-host life cycles are preferred to those with multi-host life histories because they do not require information on the distribution and abundance of the other hosts involved.
2. Seasonal migrations
   a. The main criteria is the selection of a parasite which can only be acquired in certain areas of the migration route.
   b. It is helpful if the parasite is relatively short lived so that the parasite does not accumulate in the host over a period of time, thus masking the time of infection.
3. a. The purpose of these studies are to determine which spawning grounds contribute adolescent fish to an adult population; therefore, infections should be limited to the nursery grounds.
   b. For maximum usefulness, the parasite should be permanently identifiable in the infected host.

The following are several examples of the use of parasites to study various aspects of herring populations.

Among the first to use parasites in herring population studies was Shulman and Shulman-Albova (1953) in the White Sea and Bishop and Margolis (1955) off British Columbia. Sindermann (1957) used several larval and adult helminth parasites, a protozoa, and a fungus as indicators of herring movement and stock separation off the northwestern Atlantic coast. He concluded that adult herring in the Gulf of Maine and the Gulf of Saint Lawrence represent separate populations. Further, he indicated that the immature herring in the eastern and western parts of the Gulf of Maine may be separate populations and that these immature fish do not move laterally along the coast of Maine.

MacKenzie (1974, 1978) used two forms of the larval digenetic trematode Renicola and the larval cestode Lacistorhynchus to trace the juvenile recruitment migrations of herring in the North Sea. He compared the prevalence of infections in the juvenile fish taken on the nursery grounds from off Scotland (Moray Firth and Firth of Forth; Renicola spp. = <70%, Lacistorhynchus = 0%) to the fish collected on the nursery grounds off Denmark (Bløden; Renicola spp. = 1%, Lacistorhynchus = 15%). These prevalences were compared to the adult herring collected off the Shetland Islands (Renicola spp. = <1%, Lacistorhynchus = 15%). MacKenzie concluded that most of the adults found off the Shetland Islands were recruited from the Danish nursery grounds. In addition, he followed the prevalence of these same infections in the Minch herring fishery (off the west coast of Scotland) over several seasons. The age-related changes in prevalance indicated a continuous immigration of juveniles from Bløden to Minch.

Recently, Arthur and Arai (1980) used various statistical methods to analyze the parasite species found in herring from British Columbia, Washington, and Alaska. They concluded that although their study could not separate adjacent spawning stocks, future work may show parasites useful for stock separation in several of the areas studied and for areas more geographically widespread.

The use of parasites as biological indicators of the hosts' activities is basically a crap-shoot. The chance of success cannot be predicted a priori. The overall goal is to determine the distribution of the host, not just the parasite. However, if the above recommendations are followed, parasites can be very valuable in herring population studies.

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FEASIBILITY OF SCALE PATTERN ANALYSIS TECHNIQUES FOR STOCK IDENTIFICATION AND GROWTH OF PACIFIC HERRING, *Clupea harengus pallasi*, FROM FOUR SPAWNING LOCATIONS OF THE EASTERN BERING SEA

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Domestic exploitation of Pacific herring (*Clupea harengus pallasi*) in the eastern Bering Sea has expanded substantially the past five years. The Togiak region, of Bristol Bay, supports the largest sac roe and roe-on-kelp fishery along the eastern Bering Sea coast (Fig. 1). Commercial fisheries are also developing in Norton Sound and Cape Romanzof. The increasing domestic fishing effort on spawning populations, controversial offshore foreign joint ventures, exploitation for food and bait, and dependence of coastal villages upon herring for subsistence, require an understanding of the biology and composition of these spawning stocks so that all interests may be considered in development of management policies for the eastern Bering Sea fisheries.

Identification of herring stocks in North Sea mixed fisheries (Cushing 1968), North Pacific and Canadian Arctic (Riske 1960), and Newfoundland (Tibbo 1956) has been accomplished using the first year's scale growth and additional meristic characteristics. Three herring spawning populations have been identified along the Gaspé Coast and St. Lawrence River by otolith growth patterns and meristic characteristics in a discriminant function analysis (Cote 1980). The Alaska Department of Fish and Game (ADF&G) has successfully developed stock separation techniques for identification and management of some salmon stocks using scale pattern analysis (Krasnowski 1978, Bethe 1979, 1980, Cross 1980). These techniques were modified and applied to herring data collected from spawning populations along the eastern Bering Sea coast. The results of this investigation are summarized here. The objective of this paper was to study scale growth patterns and backcalculated lengths of four age classes of herring sampled at four spawning locations along the Bering Sea coast from 1978 and 1979 to determine:

1. Within season temporal variation in scale characteristics for herring from the Togiak District during 1977, 1978, and 1979 seasons, consistency in scale and growth patterns by gear type, and year for 1974 and 1975 brood years of herring sampled at a specific spawning location in successive years.

2. Difference in growth expressed by backcalculated lengths and growth increments of four age classes of herring from four spawning locations.

3. The feasibility of using scale pattern data in discriminant function analysis to identify stocks of herring sampled from the four spawning locations.

Bimodality of the length frequency curve for Port Clarence age 5 herring collected in 1979 indicates presence of at least two populations at Port Clarence, the same day. Scale variables and fish lengths for herring from Togiak, an area separated by considerable distances from Port Clarence, did not exhibit differences for each age class either by distribution or in relation to time. These findings indicate that fish lengths and scale variables can be used to characterize herring populations along the eastern Bering Sea coast, and support the distinction of two groups of herring at Port Clarence in 1979. Because backcalculated lengths are computed by use of scale measurements and fish lengths, these trends are reflected in the backcalculated data. Backcalculated lengths at age overall were largest for Togiak herring, smallest for Cape Denbigh herring, similar for Port Clarence B, Cape Denbigh, and Cape Romanzof herring, and smallest for Port Clarence A herring.

Significant differences were not evident by gear type for backcalculated lengths for 1979 age 5 and 1979 age 6 herring in the Togiak fishery. Therefore, consideration of gear type is of little concern for comparison of older herring from Togiak mixed gear fisheries to commercial gillnet fisheries in northern Bering Sea fisheries. In contrast, however, the 1979 age 3 purse seine caught herring from Togiak were smaller than the herring caught by variable mesh gillnet. This difference did not interfere with growth differentiation of this age class with Cape Denbigh herring.

Growth of herring of one brood year spawning in a specific location is highly variable from one year to the next from resulting environmental conditions which also differ from year to year. Growth rates between annuli may be shared for herring from adjacent spawning locations. This variability however, results in growth patterns characteristic of each population and age class. Growth curves were distinct for each age class. Togiak herring proved consistently discrete from all of the northern populations for all comparisons. Cape Denbigh and Cape Romanzof were similar for the 1978 age 4 samples, and did not show differences in growth curves with Port Clarence B herring, indicating that these populations were combined or mixed during those spawning years. Port Clarence A herring proved to be significantly different from all locations. Similarities in growth curves were not evident for Cape Denbigh and Cape Romanzof for the 1978 age 6 growth curve comparison indicating no mixing for the older age class at these two locations in 1978.

Though growth is characteristic for a given population, variability between years requires consideration of each age class separately. Application of these growth characteristics by linear discriminant analysis resulted in a classification of three spawning stocks from five spawning populations. Though five spawning locations were represented only by one age class, the classification scheme was consistent for the remaining three age groups, where Cape Denbigh, Cape Romanzof, and Port Clarence B were classified as one group, with Port Clarence A and Togiak herring represented as two distinct spawning stocks. Classification accuracy ranged from 79-84%.

Though differences in herring growth occur for the same brood year between spawning periods, differences by location for each age class proved greater, resulting in the classification of one population of herring to be identified by a classification model constructed from herring sampled the previous year. Because herring populations can be characterized by growth classified by spawning location, and these characteristics can be traced by time, definition of herring stocks by spawning location is practical. Because a classification model is only as complete as the data it incorporates and because of the large geographical area considered in this study, only extensive examination for several years in numerous areas along the coast would identify actual population or stock borders and the extent of mixing between areas.

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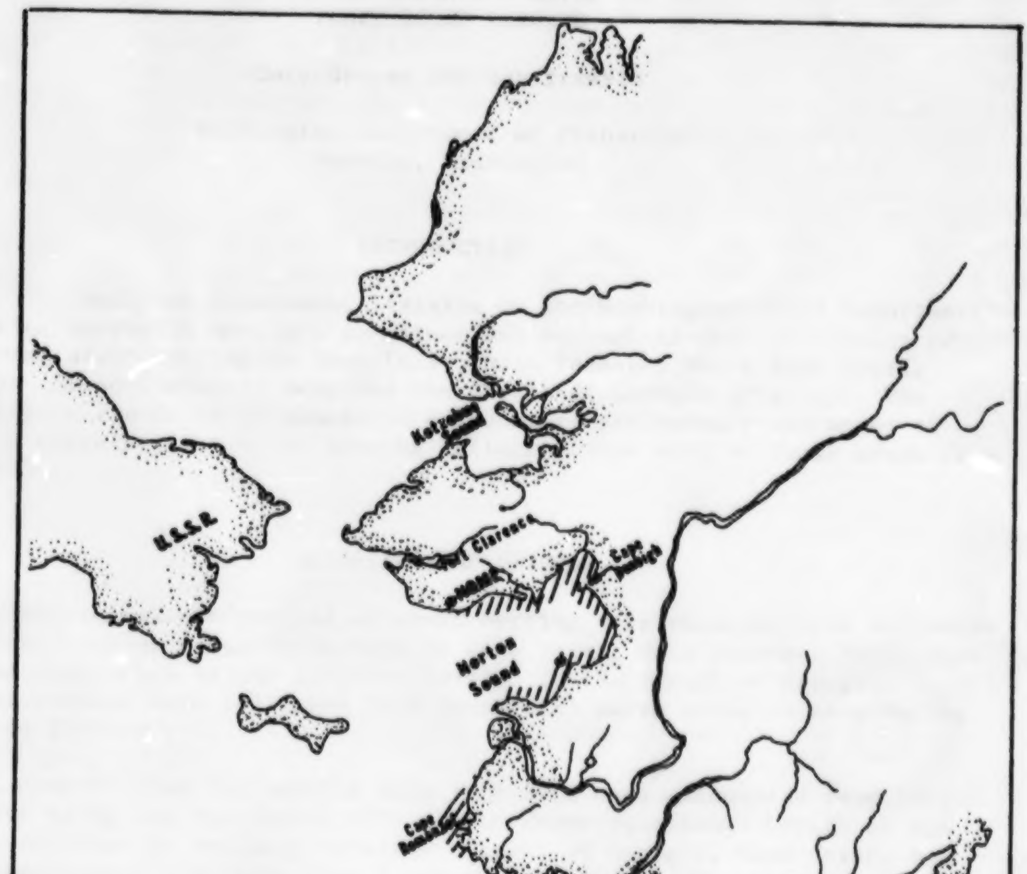

Figure 1. Location of major commercial fishing areas on the eastern Bering Sea Coast.

GROWTH AND MORTALITY RATES FOR PUGET SOUND HERRING

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INTRODUCTION

The Baitfish Management Division of the Washington State Department of Fisheries currently monitors abundance and biological characteristics of pre-spawning adult herring in Case Inlet, Hale Passage, North Hood Canal, Protection Island-Discovery Bay, and the Strait of Georgia (Fig. 1). The intent of this report is to summarize and compare preliminary estimates of growth and mortality rates for herring collected from each of these areas from 1974 to 1978.

MATERIALS AND METHODS

Biological sub-samples of adult herring were obtained from mid-water trawl catches during research surveys in Case Inlet, Hale Passage, North Hood Canal, and Protection Island (Lemberg 1978). In the Strait of Georgia, herring biosamples were collected from commercial purse seine catches during the sac-roe fishery.

Growth rates for herring from each area were calculated from length at age data using the von Bertalanffy growth curve equation. Length at age data were analyzed in two data subsets: Strait of Georgia, Case Inlet, and Hale Passage comparisons were made first with North Hood Canal, secondly with Protection Island. Differences between growth curves for fish within each subset were statistically tested using a least squares analysis (Kimura 1980).

Mortality estimates were calculated using methods from Chapman-Robson (1960). Number of fish at age from the biological samples, unweighted by catch rate or population biomass, were used for North Hood Canal, Protection Island, Case Inlet, and Hale Passage. This method yielded a mortality estimate for each sampling year. Total herring biomass estimates for the Strait of Georgia were derived from a combination of acoustic-trawl, catch and escapement data (Trumble 1977). The age composition of the overall population was estimated from the purse seine catch data. This data was converted from biomass to numbers at age using the average weight at age. This method allowed mortality estimates to be calculated by year class.

RESULTS

Von Bertalanffy growth curve parameters for the five areas are presented in Table 1. The Strait of Georgia fish had the highest L_∞ estimates, 263 mm, and the lowest K estimate, 0.36. Case Inlet fish had the smallest L_∞ estimate at 197 mm. Herring from North Hood Canal, Protection Island, and Hale Passage had similar L_∞ estimates of 226, 227, and 230 mm and

K estimates of 0.60, 0.56, and 0.48, respectively. Significant differences were found at the 1% level in the L∞ and K estimates for the Strait of Georgia, Case Inlet, and Hale Passage (Trumble 1979). There was no significant differences in t_0 values for these areas. No significant differences were found in the von Bertalanffy parameters for North Hood Canal and Protection Island herring.

Estimates of total instantaneous mortality rates (Z) are presented in Tables 2 and 3. The average Z estimates ranged from 0.49 for both North Hood Canal and Protection Island to 0.53 for the Strait of Georgia. Mortality estimates for Case Inlet and Hale Passage were excluded since year to year fluctuations in age class abundance in the biosamples resulted in unrealistic Z values.

DISCUSSION

Differences noted in the growth rates of herring suggest that there are at least three separate stocks within Puget Sound (Fig. 2). The Strait of Georgia herring are the largest and have the slowest growth rate of herring from the areas analyzed. Case Inlet herring have the lowest L∞ estimate and one of the fastest growth rates. Von Bertalanffy growth curve parameters for herring from North Hood Canal and Protection Island are not significantly different from each other and are very similar to Hale Passage growth curve values.

The average total instantaneous mortality rate (Z) of 0.49 for North Hood Canal and Protection Island is slightly lower than the Z estimate of 0.53 for the Strait of Georgia stock. However, the Protection Island-North Hood Canal fish are not harvested as adults, while the Strait of Georgia fish are harvested at an approximately 20% rate. Mortality estimates are being updated for all areas for the years 1974 to 1980 and suggest that the estimated total mortality in the Strait of Georgia will increase to about 0.6.

A weakness of this report is the lack of a comparable unit of analysis between areas. Estimates of total biomass at age and numbers at age will be generated for areas in addition to the Strait of Georgia. This data will subsequently be utilized for mortality estimates.

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Table 1. Least squares estimates of L^∞, K, t_0 (Von Bertalanffy growth parameters) for Puget Sound herring stocks.

Area	L^∞	K	t_0
Strait of Georgia	263	0.36	−0.15
Hale Passage	230	0.48	−0.10
Protection Island	227	0.56	0.07
North Hood Canal	226	0.60	0.05
Case Inlet	197	0.59	0.14

Table 2. Instantaneous total mortality rates for herring aged 4 and older from Protection Island and North Hood Canal.

	Total mortality rate (Z)	
Collection year	Protection Island	North Hood Canal
1974	0.48	-
1975	0.50	0.34
1976	0.43	0.68
1977	0.55	0.59
1978	0.48	0.35
Average	0.49	0.49

Table 3. Instantaneous total mortality rates for herring aged 4 and older from the Strait of Georgia.

Year class	Total mortality rate (Z)
1967	0.72
1968	0.57
1969	0.55
1970	0.45
1971	0.40
1972	0.51
Average	0.53

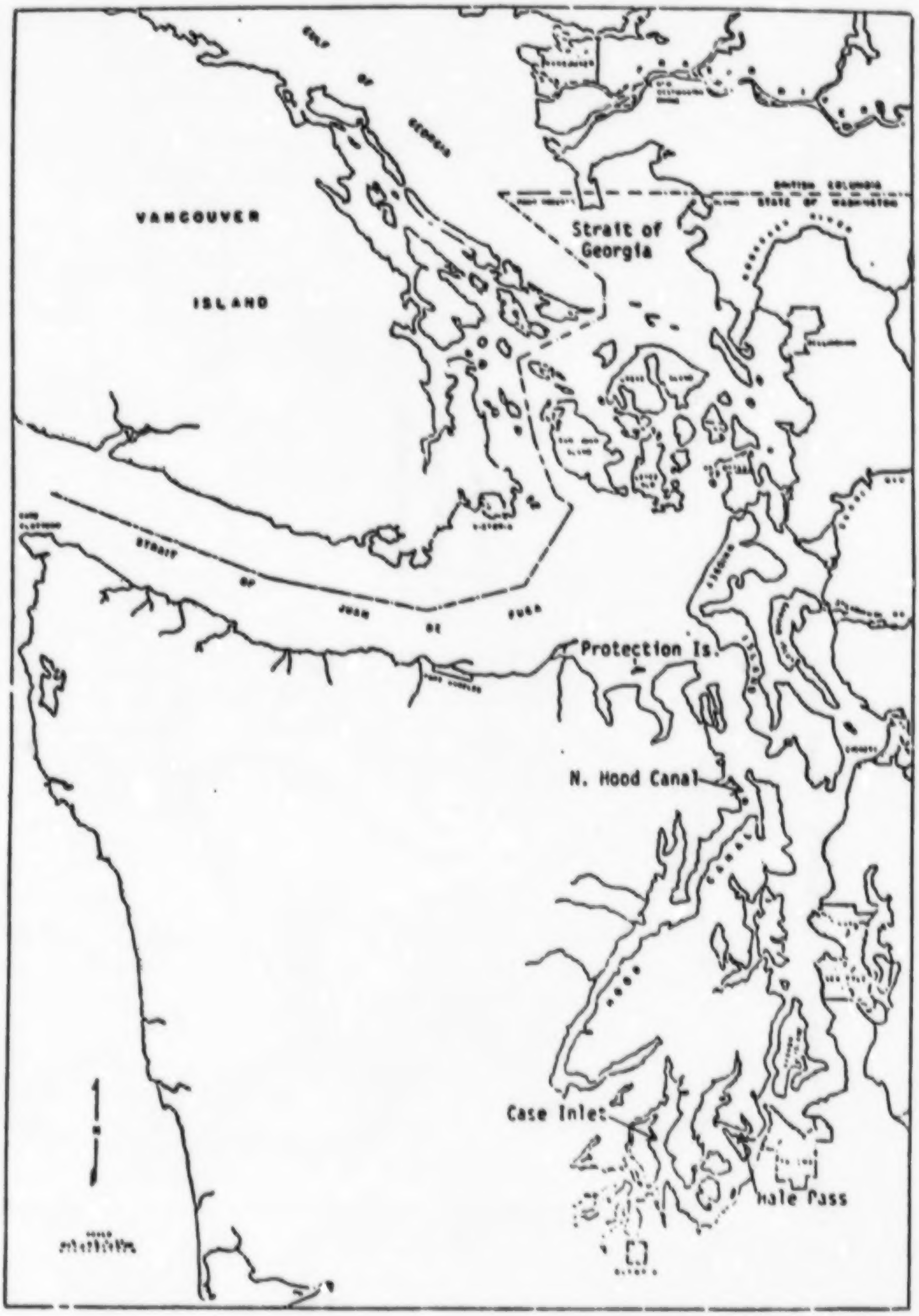

Figure 1. Areas presently surveyed for adult herring concentrations by the Baitfish Management Division.

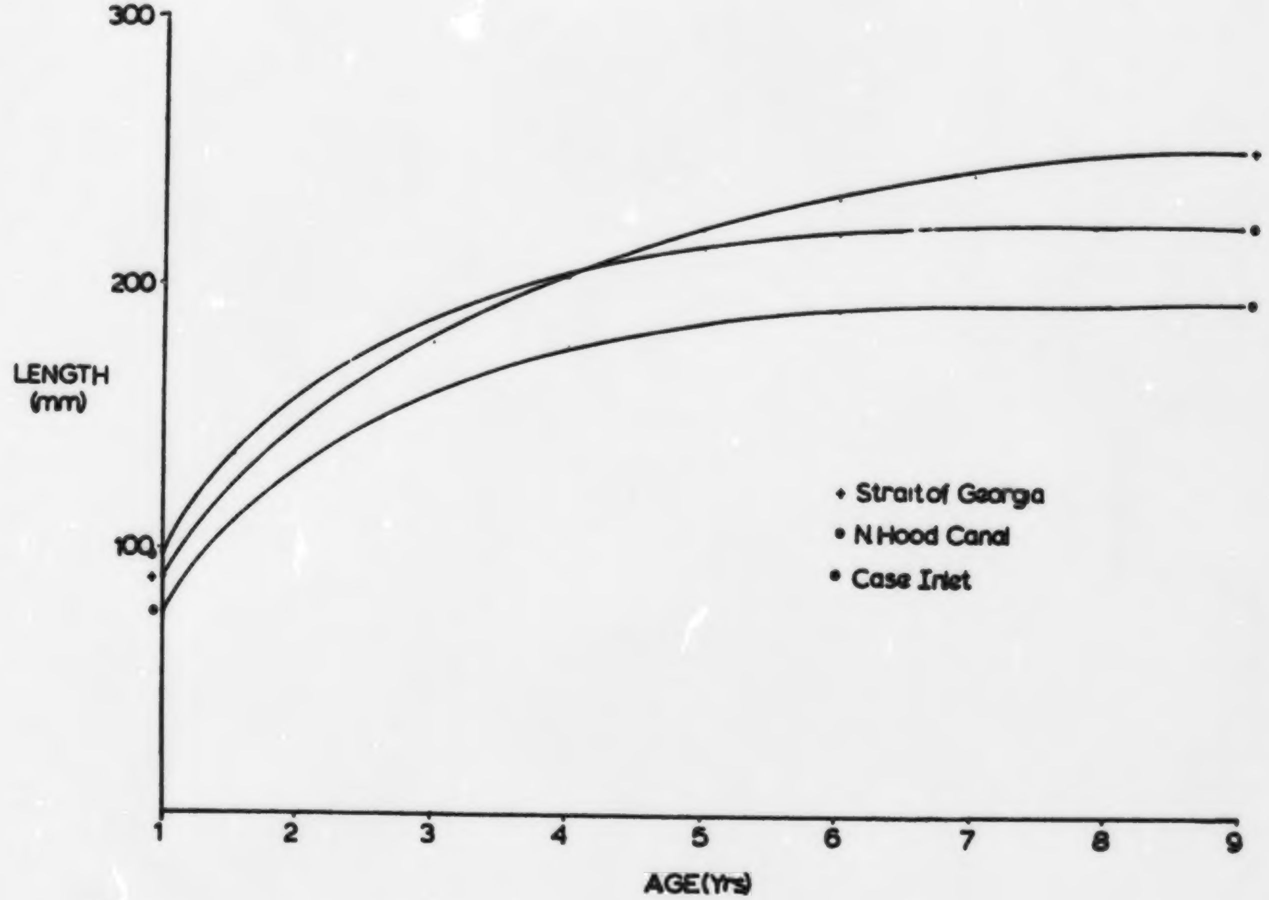

Figure 2. Von Bertalanffy growth curves for herring from three areas of Puget Sound.

SESSION VII:

TAGGING

HERRING TAGGING IN B.C.

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In British Columbia the herring roe fishery is polarized into a few geographically separated areas characterized by the historic occurrence of spawnings of considerable magnitude. A food and bait fishery operates on assemblages of migrating or holding fish that may spawn near or far from the fishing areas. Biomass estimates are made hydroacoustically offshore and near the fishing grounds to provide information for the determination of catch quotas and the timing of fisheries. It is considered important by managers and biologists involved in stock assessment and catch forecasts to know the discreteness and migratory movements of these stocks.

Herring populations were defined for the coast of British Columbia for the reduction fishery from tagging studies extending over 31 years (1936-67). The general conclusion was that there existed 13 major migratory populations. The major populations were considered subject to various degrees of emigration and immigration. Over the many years that this tagging data was collected, herring were tagged and recovered in all seasons, but were principally tagged at spawning time between February and April and recovered in the reduction fishery between November and January. By the nature of the reduction fishery, this tagging data cannot provide us with information on whether herring return to spawn on the same grounds year after year, yet the management strategy for this fishery assumes this fidelity. The food and bait fishery in the inside waters is also a pulse fishery that harvests the total catch from one major aggregation over a short period of time and thus may operate on a stock that should also support a roe fishery.

To address these management needs, a tagging program was initiated in 1979. An anchor tag was selected as most suitable based on trials in food and roe processing plants by Hay and others, which showed tag recoveries of 30% in the former and 80% in the latter. Experiments were also conducted by Hay to determine tagging mortality and tag retention.

A tagging program was designed and implemented for the whole coast where herring were to be tagged at spawning on all major spawning grounds, during food and bait fisheries, and on major migratory routes inshore and on fishing grounds offshore and recovered during the various fisheries. Fish are tagged from seine catches (except offshore where they are also tagged from trawl catches). Recaptures are from trawl (food and bait), seine (food and bait and roe), gillnet (roe), bait pond and roe-on-kelp fisheries and from predator stomachs. Tag returns are facilitated by the distribution of posters and tag return envelopes.

There have been four seasons of tagging to date. In the fall of 1979, 4,500 herring were tagged principally in the lower Strait of Georgia. In the spring of 1980, 48,000 herring were tagged throughout the coast of B.C. In the fall of 1980, 30,000 herring were tagged offshore the west coast of Vancouver Island, during the north coast food fishery in Browning Entrance, and in Johnstone and Georgia straits. In the spring of 1981, 81,000 herring were tagged, again throughout the coast of B.C. In addition, the fall 1981 tagging has begun with 10,000 herring tagged offshore in September.

The return of 1,572 tags was projected for the first year at large for taggings made in the 1979-80 season. Only 70 tags with good return information were recovered. There are several potential causes for this low return: polarization of the fisheries, lower catches than anticipated (catches were 90,000 t in 1978, 57,000 t in 1979, 18,000 t in 1980, and 40,000 t in 1981), greater tagging mortality and tag loss than estimated, lower recoveries in processing plants than estimated, and a higher incidence of poor quality recovery information than anticipated. There have been recoveries from 30% of the 255 taggings to date (from 40% of the 71 taggings made in the 1979-80 season). The highest return from an individual tagging was 6.3% return after 18 to 49 days at large. A tagged fish at large for 482 days was the longest at large and was from the first tagging. There have been some interesting results to date but because the program is only just entering its third season and tag returns have been small, no major conclusions can be drawn. From the experience to date and because of cutbacks in funding, the tagging program is changing its objectives. Instead of attempting to define stocks and migration routes for the whole coast, the effort will be directed at some specific objectives that have the most pressing need and promise the greatest success.

Activities planned for the near future include:

1. Further technological development - by determining the most suitable tag and obtaining additional information on tag loss, tagging and associated mortality, expected rate of return of captured tags, and improving the quality of tag return information.

2. Tagging in selected areas of the coast (west coast of Vancouver Island, Strait of Georgia, North Coast) to identify stocks and determine their migration routes on a spatial and temporal scale.

3. Tagging in holding areas prior to the roe fishery where rapidly migrating stocks may confound pre-fishery echosounder estimates of stock size.

RETENTION OF TAGS AND SURVIVAL OF TAGGED PACIFIC HERRING HELD IN CAPTIVITY

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ABSTRACT

Herring were tagged and maintained in captivity for 18 mo to determine the effects of tagging on survival and estimate the rate of retention of tags. Initial mortality within 2 mo of tagging was low, varying between 2% and 18% among 3 separate groups. Lowest initial mortality occurred among one group held in captivity the longest (14 mo) prior to tagging. After 6 mo there was no evidence of reduced viability of tagged fish compared to untagged fish held in the same enclosures: comparison of length-weight regressions and gonosomatic indices between tagged and untagged fish showed no significant differences. Mortality continued gradually throughout the duration of the test but increased suddenly after approximately 16 mo during an outbreak of disease. Several months after the start of the tests loose tags lost from live herring were found on tank bottoms. The frequency of loose or unrecovered tags (loose tags that were lost in drains) was estimated at 9% after 6 mo and 22-26% after 18 mo. Mortality due solely to tagging is probably not substantial within the first year after tagging. However, the rate of tag loss from fish is high. Special attention to this problem may be warranted in the design of future tagging and tag recovery programs.

MARKING JUVENILE HERRING WITH FLUORESCENT PIGMENTS

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INTRODUCTION

A pilot project was conducted by the staff of the Baitfish Management Unit of the Washington State Department of Fisheries during August 1980 to test the effectiveness of spray marking juvenile herring with fluorescent pigments. Fluorescent marking has been used successfully with juvenile salmonids and numerous other species (Jackson 1959, Knudsen & Herke 1978, Andrews 1972, Engelhardt 1977, Phinney & Mathews 1969, Phinney, Miller & Dahlberg 1967, Pribble 1976), but has not been attempted with herring. One advantage of using fluorescent pigment is that the mark is only apparent under ultra-violet (UV) light and would not attract predators under normal lighting conditions. A practical mass marking technique for juvenile herring in conjunction with a sampling program for recaptures could help answer questions on juvenile migration patterns and mixing of stocks in Puget Sound. The following questions will be addressed in this report:

1. what is the percentage mortality due to the marking procedure,
2. what is the percentage mortality due to handling and holding,
3. how long is the mark retained, and
4. how effective is this procedure for marking herring.

MATERIALS AND METHODS

Juvenile (0^+ and 1^+) herring were collected on July 28 and August 4, 1980 with a 45.7 by 3.0 m beach seine with a stretch mesh size of 1.3 cm from the boat launching area near the southwest end of the Fox Island bridge in southern Puget Sound. The fish were dipnetted from the seine into large tubs of saltwater and immediately transported by boat to several 4.9 × 4.9 × 3.0 m saltwater holding pens (at the WDF Fox Island salmon rearing facility) approximately 1.5 km away from the sampling site. All fish were held for at least two days before marking to allow for mortalities due to collection to occur.

Juvenile herring anesthetized with MS-222 were weighed in a bucket of saltwater, then poured onto a 3 × 9 cm screen (with a stretch mesh size of 4 mm). Another screen of similar dimensions was placed on top. Two passes with the marking gun were made on the first side, and an additional one to two passes made with the screens flipped over. The distance from the nozzle of the marking gun to the screen was 38 cm for the first group marked (1^+ herring) and 33 cm for the second group marked (0^+ and 1^+ herring). A SCUBA tank of compressed air was used to maintain a constant delivery pressure of 100 psi. Two colors, Rocket Red and Arc Yellow, of Jeffrey Mill grind pigment with particle sizes ranging from 30 to 350 μ were used. The marked fish were then placed into a separate holding pen for the duration of the experiment.

The first group of herring was marked on July 30, 1980 and held for five weeks. The second group, marked on August 6, 1980, was held for four weeks. Samples were taken weekly from each group, frozen, and later checked under a UV light for mark retention. The intensity of the marks was examined by classifying the marked fish into three subjective categories, (1) well - many pigment granules on body and opercle (2) moderate - pigment granules on body and/on opercle, and (3) light - less than 20 pigment granules on body only.

Control groups of 0^+ and 1^+ herring were held in separate pens for the duration of the experiment. These fish were not handled after their initial capture. The control and marked groups are assumed to have received the same amount of stress aside from the marking process. Both groups were checked for mortalities once a week, a procedure that stressed the fish since the holding nets had to be lifted almost completely out of water.

RESULTS

The first group of 264 1^+ herring (1^+ mean length = 128 mm) was marked in one and half hours with a Rocket Red pigment. A second group included 194 1^+ herring marked in an hour using an Arc Yellow pigment and 797 0^+ herring (0^+ mean length = 79 mm) marked in one and a half hours with a Rocket Red pigment. The time for the actual marking, from when the fish were poured onto the screen until they were released in a pen, averaged 30 to 45 seconds.

Initial mortalities due to capture and marking were low. Two 0^+ and two 1^+ mortalities occurred during the initial two day holding period and one 1^+ herring in the first group died during the marking operation. Delayed mortalities throughout the experiment were low. In the first marked group of 1^+ herring, eleven (4%) mortalities occurred in five weeks. For four weeks of observations on the second marked group, three mortalities (2%) of 1^+ herring and seven mortalities (1%) of 0^+ herring occurred. A total of 188 1^+ herring were held as a control group. The exact number of 0^+ herring held as a control group was not determined. Mortalities in the control group of herring were low with four 1^+ (2.1%) and nine 0^+ deaths during the study. Some scale loss was evident during handling and marking but no adverse affects such as fungus growths or Vibrio were noticed. Overall the condition of both the marked and control group was excellent.

Table 1 lists the number of herring examined under UV light each week for mark retention and the intensity of their marks. Mark retention at the end of the study was 100% for all three groups of herring marked. The "light" category probably would not be apparent if large numbers of herring were visually sampled for marks at the bait processing plant using UV light. The marks in the light category were not obvious compared to the other two categories. The "well" and "moderate" categories comprised 82% to 91% of the total marked fish in this study. These intensities are quite apparent under UV-light inspection.

Newly marked fish were highly visible to the naked eye. For some fish, pigment was sloughed off the mucus layer slowly. The pigment was still visible on some 0^+ and 1^+ herring under natural light conditions after five weeks.

DISCUSSION

This was the first known attempt at marking juvenile herring with fluorescent pigments. We observed a 100% mark retention for all groups in this study. Data in the literature suggests that fluorescent marks persist up to two years on coho salmon (Phinney and Mathews 1973). Whether we could expect fluorescent marks on herring to last this long is unknown. If saltwater holding pen space was available, a long term mark retention study should be conducted.

To study migration patterns in Puget Sound, a large number of herring would have to be marked in a relatively short period of time. To satisfy this requirement marking operations would have to be conducted in areas where herring were readily available. A suitable recovery system would also have to be established involving Puget Sound bait processors as well as subsequent WDF herring sampling efforts. Marked fish would not have to be held for 4 to 5 weeks but fish released immediately after marking would still have pigment adhering to the mucus layer and could be visible to predators. Reducing the number of passes made with a marking gun to one per side would lower the amount of excess pigment and reduce the time that the mark is visible under natural light.

The methods we utilized are only adequate to mark a small number of herring. Since we now know that herring can survive the trauma of the marking procedure with very few mortalities and with good mark retention, another experiment should be conducted with a simulated production system that could mark several thousand fish per hour versus the two hundred fish per hour for 1^+ and five hundred fish per hour for 0^+ obtained in this study. The marking trough system currently being used for small salmonids by the WDF and the Fisheries Research Institute at the University of Washington could serve our needs with only a few minor modifications. A marking program, in conjunction with the circumstantial evidence for movement patterns collected thus far by the Recruitment Studies project, could help to define migration patterns of juvenile herring within Puget Sound.

ACKNOWLEDGMENTS

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Table 1. Mark retention samples for 0+ and 1+ herring marked with fluorescent pigments.

Date of Sample	# in Sample	Age	Pigment Color	Mark retention well	moderate	light	Duration (in days)
8/ 1/80	13	1+	Rocket Red	11	2	0	2
8/ 6/80	10	1+	Rocket Red	9	1	0	7
8/13/80	19	0+	Rocket Red	11	8	0	7
8/13/80	8	1+	Rocket Red	6	2	0	14
8/13/80	13	1+	Arc Yellow	7	6	0	7
8/20/80	32	0+	Rocket Red	17	15	0	14
8/20/80	4	1+	Rocket Red	1	3	0	21
8/20/80	7	1+	Arc Yellow	5	2	0	14
8/27/80	36	0+	Rocket Red	21	7	8	21
8/27/80	11	1+	Rocket Red	11	0	0	28
8/27/80	8	1+	Arc Yellow	0	6	2	21
9/ 3/80	703	0+	Rocket Red	369	205	129	28
9/ 3/80	207	1+	Rocket Red	131	53	23	35
9/ 3/80	163	1+	Arc Yellow	68	62	33	28
Totals*	797	0+	Rocket Red	424 53.3%	235 29.5%	137 17.2%	**
	264	1+	Rocket Red	178 67.4%	63 23.9%	23 8.7%	
	194	1+	Arc Yellow	82 42.3%	77 39.7%	35 18.0%	

*including mortalities.

**one mortality with no discernable mark due to deteriorated skin.

CODED WIRE MICROTAGS AND HERRING

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ABSTRACT

Coded wire microtags, widely utilized for salmon research and management, appear to be comparably effective when applied to Pacific herring (Kreiger 1978). Current experiments, relating both to tagging and recovery aspects, are being carried out in the North Sea and on the west coast of Scotland. In that context, a relatively simple detecting system, capable of 15-20 tons/hr throughput with 100% detection efficiency, is described by Corten (Corten 1980).

Extension of the detection technique to larger sizes - throughput 25-50 tons/hr - and automatic separation of the tagged specimen, appears to be straightforward.

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TAGGING HERRING WITH CODED-WIRE MICROTAGS

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ABSTRACT

Adult herring were tagged using coded-wire microtags and held for 13 mo in a circulating seawater tank. The implantation site was the anterior geniohyoideus muscle of the lower jaw for fish >190 mm FL; smaller fish were tagged in the posterior geniohyoideus muscle. Of the 136 fish tagged, 81% survived; 98% of the survivors retained tags. Deaths were attributed to heavy scale losses caused by repeated handling. During shipboard experiments, an average of 10 fish were tagged per minute. Anesthesia was not used. It appears that the coded-wire microtag system originally designed for salmonids can be used with little modification to tag herring quickly and effectively. Good tag retention and low tagging mortality result.

Mr. Krieger was unable to attend this workshop but sent this summary for inclusion in the Proceedings.